# THE EXPLOSIVES ENGINEER

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SEPTEMBER-OCTOBER · 1960

VOLUME 38-NUMBER 5

TDM Self-Propelled Carrier has U-Bar construction which permits drilling true vertical holes on rugged terrain. Wide crawler pads and long ground contact give exceptional stability.

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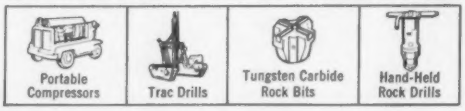


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# THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction


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**Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.**


In this day and age of towering skyscrapers, multimile tunnels, and gigantic hydroelectric dams, it takes an extraordinary engineering and construction project to stir up more than a normal amount of interest in the circles frequented by the Moles and the Beavers. There is just such a project—the Glen Canyon Dam in Arizona—now about midway to completion.

In its immensity, the Glen Canyon project is a job that staggers even the most imaginative person; the complexity of the many technical problems encountered tests the engineering skill and practical know-how of the most experienced contractor.

An indication of the size and difficulty of this job is the amount of preliminary construction work necessary before engineers, surveyors, and prospective bidders could visit the job site. Located miles from the nearest habitation, the site of the Glen Canyon Dam is in a lonely area of Navajo country whose only occupants were the Indians and their herds of sheep and goats. Roads, airplane-landing strips, bridges, and other facilities had to be built at a cost of several million dollars to make this area accessible.

The job itself can be described only by superlative: It is the largest single contract ever let by the U. S. Bureau of Reclamation, a bureau that has let some mighty big contracts in the last few decades; it is possibly the largest job going on in the world today; and the prime contractor—Merritt-Chapman & Scott of New York City—is observing its 100th anniversary this year.

One of Lewis Nordyke's last assignments for THE EXPLOSIVES ENGINEER before his recent sudden death was to visit the Glen Canyon Dam project and to describe in his clear and interesting way not only the scope and technical aspects, but also his impressions of this tremendous undertaking. His article, "The Great Glen Canyon Dam Project," starting on page 135, proves that he fulfilled this assignment with his usual skill.

While on the subject of Glen Canyon Dam, we feel it only proper to thank the U. S. Bureau of Reclamation for the fine storytelling and dramatic photographs it supplied for illustrating the article. Our difficulty was not in finding enough photographs for our use but in making a selection from the hundreds of excellent photos available.

We are most grateful for the cooperation of the Bureau and happy to say: "Photos, courtesy of the U. S. Bureau of Reclamation."

* * *

The expression "Thar's gold in them thar hills" does not apply to Kings Mountain in North Carolina; but the Foote Mineral Company, which operates an open-pit mine in this area, isn't the least bit concerned about the lack of this precious material. This 85-year-old company is taking out a metal, lithium, that has an ever-expanding use in industry, and new applications are being found for the by-products of this operation.

The Kings Mountain area is one of the few sections, and perhaps the most important, in the United States endowed by nature with pegmatites containing lithium ore. However, some difficulties were encountered in mining, and a selective system was devised to remove the ore and the waste material.

Neil O. Johnson, manager of Foote's operations at Kings Mountain, presents an informative article on the drilling and blasting procedures used at this property. The article starts on page 148 and, in addition to its technical value, relates some interesting historical high lights of the locale, and describes some of the end uses of the unusual material mined there.


EDITORIAL STAFF: JAMES J. O'NEILL, *Editor*; THOMAS E. MILLER, *Associate Editor*; GERTRUDE A. DONNELLY, *Associate Editor*; EDWARD L. GRANT, *Art Editor*; HOWARD B. DICKSON, *Production Manager*; A. J. ACKERMAN, *Advertising Manager*; MONTGOMERY R. BUDD, *Director*.

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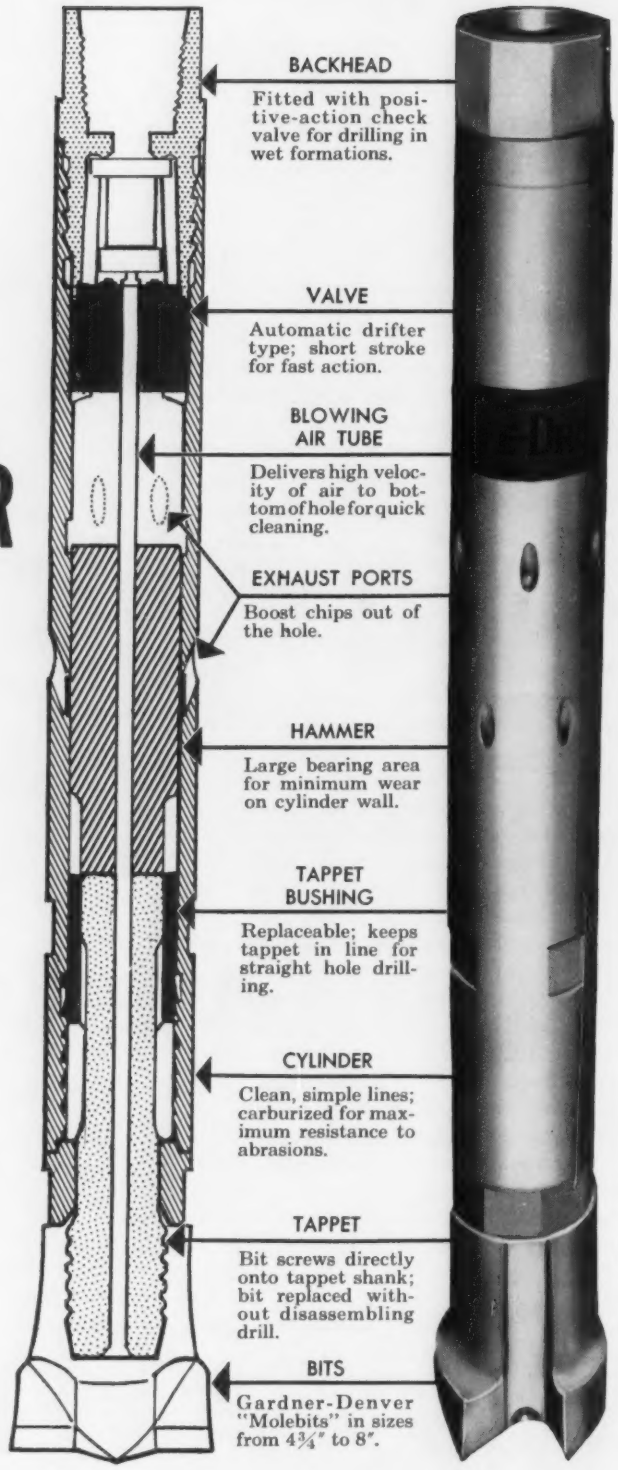
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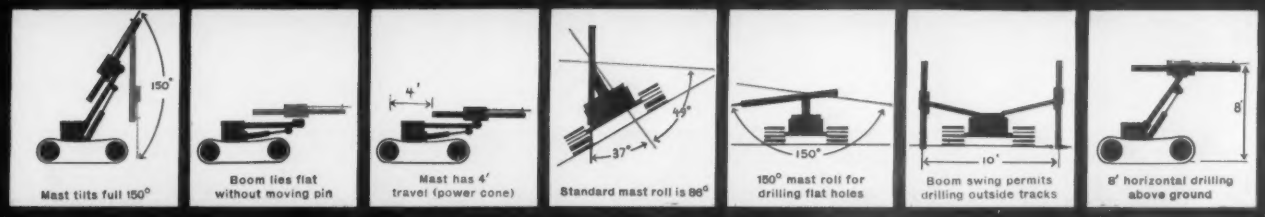

## New Blue Brute 4½" Crawler Drill . . .

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From crawler tread to striking bar, this new 4½" crawler drill is designed to get 5-10% more footage per drilling dollar. Its simpler construction, a more stable platform and easier control get more uninterrupted footage every drilling day.

Check out the all-new Blue Brute 4½-inch drill. It's built with the famous Worthington valve, the rugged rifle bar, heat-treated alloy-steel bushings at important wear points, and special analysis steel for *extra* strength. These and many other proven Worthington features mean least air consumption, less maintenance and downtime.

Look at the new Worthington mast! Five-inch channels and an all-welded assembly take full drill torque with strength to spare. And a more powerful feed motor shifts drill up and back more quickly for faster steel changes.

Look at the crawler carrier! An automatic line oiler is readily adjusted to lubricate drill, feed motor, hydraulic pump and tramming motors. The latter are 8 hp, giving a total drawbar pull of 6,000 pounds—enough to haul a 900′ compressor almost anywhere.

There's better operator safety, too! Carefully positioned boom and mast stops prevent over-balancing. And controls are placed for safer operation. But the basic stability of design permits the wide range of movements shown.

For more information about this new Blue Brute drill, call your Worthington rotary compressor distributor listed in the yellow pages. Or write Worthington Corporation, Dept. 60-29, Holyoke, Mass. In Canada: Worthington (Canada) Ltd., Brantford, Ontario.

WORTHINGTON

FRANCIS CAMERON

## Francis Cameron

PRESIDENT

ST. JOSEPH LEAD COMPANY

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### A Biography

FRANCIS CAMERON, president of St. Joseph Lead Company, believes firmly that the metals this country needs can be found whenever there is sufficient demand for them, and he stoutly maintains, "If you could promise me 25 cents a pound for lead, I'd have it running out of your ears."

His record with St. Joe indicates this statement is not idle talk. He has shepherded the Indian Creek Mine and the Viburnum Project, both in Southeastern Missouri, from the time the first drill went down until they were brought into production, and he hopes to see the new Meramec Mine near Sullivan, Missouri, operated jointly with Bethlehem Steel Company, producing iron ore by 1963. St. Joe men found all three deposits. In the Viburnum Project, St. Joe has enough lead ore to keep that area producing for many years to come.

This ability to direct the use of the modern tools of the geologist, geophysicist, geochemist, and air photographer in a successful effort to find new ore bodies for his company had much to do with his rise to the presidency of St. Joe.

Frank (as he is best known to most miners) graduated from Leland Stanford in 1924 with a B.A. in geology, and did some graduate work in geology and mining engineering there the following year. After a short tour with the Chief Consolidated Mining Company in Utah, and with Pope Yeatman in Alaska (from whom he may have learned a few things Stanford failed to teach him), Frank joined Anaconda as engineer and geologist. For the next nineteen years he pursued the elusive metals on four continents, in a search that took him to Utah, Missouri, Montana, Northern Rhodesia, the Belgian Congo, Poland, Yugoslavia, Rumania, Canada, Alaska, Mexico, South America, and elsewhere in the Western United States. Examinations and investigations sometimes found ore, sometimes didn't; and some were in economic situations, some weren't worth bothering with. But beginning in 1945, when he left Anaconda to accept the offer of the late Clinton H. Crane, then president of St. Joe, to become assistant to the executive vice president and direct the company's mining and exploration activities, things began to happen. The three things of which Frank is proudest are the finding of the Indian Creek, Viburnum, and Meramec deposits by St. Joe men, which have put the company in an enviable position in the mining world.

Frank was elected a vice president of St. Joe a year after he joined the company, and began gradually assuming responsibility for Southeast Missouri operations as well as the company's exploration activities in other parts of the earth. He was elected a director and member of the Executive Committee in 1953, and president in February of this year.

The new president of St. Joe once played golf, but he says he gave that up about ten years ago to return wholeheartedly to his first love, fly fishing. He goes after trout, mostly in New Brunswick, Canada, where fortunately the fish are swimming not far from the company's properties, but he is ready to prospect for trout anywhere the chances of finding them look good. To meet any emergency, he has a cut-down fly rod which fits easily into a traveling bag.

Frank has not spent all his time searching for lead and trout. In World War II, he served with distinction with the Metals Reserve Company in the supervision of the foreign and domestic mineral procurement program. He served as a member of the Advisory Board of the Atomic Energy Commission on Raw Materials from 1953 to 1956; was chairman of the New York Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers in 1954; and president of the Society of Economic Geologists in 1956-57. In addition to these, he is a fellow of the Geological Society of America, a member of the Mining and Metallurgical Society of America, the Canadian Institute of Mining & Metallurgy, the Mining Club of New York, University Club of New York, Cosmos Club of Washington, and Baltusrol Golf Club.

In 1932 he married Louise Lang in Farmington, Missouri. Their two sons have left the nest and are employed: Frank K. II in San Francisco, and William L. in Arizona as a junior geologist with Anaconda.

Frank and Mrs. Cameron now live at 10 Edgewood Drive in Summit, New Jersey, dividing their time between that home and an apartment in New York City.

# Editorial

## Business and Politics

If ever there was a time when the disadvantages of an unsettled world political scene were apparent, this is it. The birth pangs of the infant Congo nation, the difficulties in Cuba, and the continued saber rattling of the Russians hold but little hope for stability over the coming year.

Contrary to popular opinion, business and industry thrive on a stable or a very slowly falling or rising price level. Steady prices make possible plans and commitments running well into the future with some hope of an operating profit. Steady prices are much to be preferred to either sharply rising or falling prices.

To the businessman or economist these things are academic and elementary, but the tragedy of it is that to the general public they are far from elementary. We believe that the average man, even in this country, is fully persuaded to the view that any big jump in prices means fat profits for the bloated businessman. The public does not know that speculative profits made from a fast rise in prices often disappear in the inventory losses brought about by the subsequent decline.

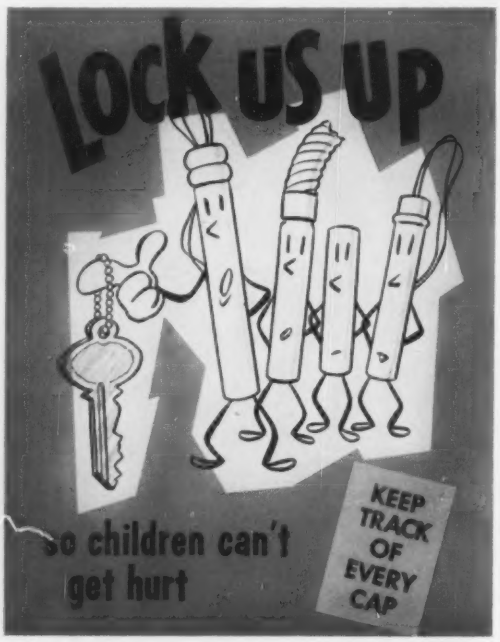
Much of the public is quite gullible to the Communist propaganda which paints the businessman as a fat pig stamped with dollar signs and wallowing in a trough of greenbacks. If only American business could make a direct attack on this absurd propaganda of the Soviets, we might get across to the peoples of the world that industry not only prefers peace for the safety of its sons and daughters, but actually would profit more from peace and stable price levels.

The Communist line which paints American business and industry as "warmongers," "war profiteers," and "bloodsuckers fattening on the woes of the people" is so far from the truth that we ought to be able to expose its fallacies with some well-aimed shots at the weak points in their argument.

## Your Key, Sir!

The sober-faced blasting cap boys are back again on the Institute of Makers of Explosives' posters to remind explosives users to lock up their blasting caps to prevent accidents to children. The same little comic strip figures appeared some years ago on the warning poster issued by the Institute to warn boys and girls to beware of caps. That poster portrayed a pistol-packin' desperado who warned his audience: "Believe me, pal, I'm very dangerous!"

THE EXPLOSIVES ENGINEER strongly urges its readers to make use of these posters by tacking them on magazine doors and wherever all who have access to caps can see them. This poster greeting a workman as he opens a magazine door or lifts the lid of a chest containing blasting caps can hardly fail to get its message across and to remind him, at the "point of sale," as the retail merchants express it, that now is the time to do something about keeping caps away from children. For years the Institute's list of "Don'ts" has contained directions for explosives users which would prevent blasting caps falling into the hands of children. Other precautions helpful in this are: Keep caps under lock and key; account for all caps at the end of the day; return all unused caps to the locked magazine at the end of the day; and permit only authorized persons to have access to the magazine. Following these suggestions will do much to cut down the numbers of boys and girls injured. The posters tell the same story, but present it in a colorful way which will attract the attention of the men on the job.

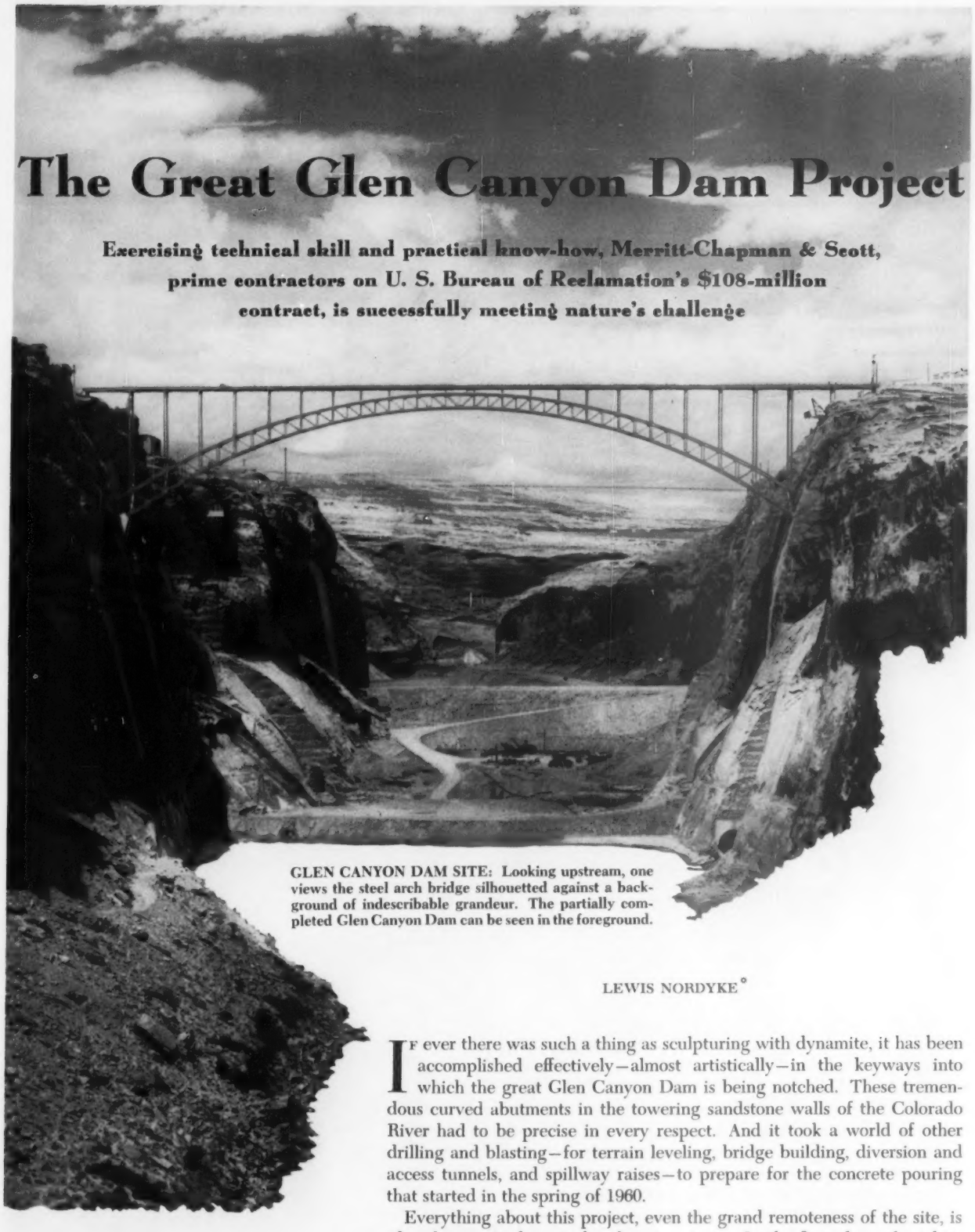



We believe the campaign to remind cap consumers of this danger may be having a good effect. At any rate, something, perhaps it is the Institute's warning campaign, is producing a small decrease in the number of children injured in recent years. Let's keep up the good work.

Copies of this poster can be obtained from the Institute of Makers of Explosives, 250 East 43rd Street, New York 17, N. Y.

# The Great Glen Canyon Dam Project

**Exercising technical skill and practical know-how, Merritt-Chapman & Scott, prime contractors on U. S. Bureau of Reclamation's $108-million contract, is successfully meeting nature's challenge**



**GLEN CANYON DAM SITE:** Looking upstream, one views the steel arch bridge silhouetted against a background of indescribable grandeur. The partially completed Glen Canyon Dam can be seen in the foreground.

LEWIS NORDYKE*

If ever there was such a thing as sculpturing with dynamite, it has been accomplished effectively—almost artistically—in the keyways into which the great Glen Canyon Dam is being notched. These tremendous curved abutments in the towering sandstone walls of the Colorado River had to be precise in every respect. And it took a world of other drilling and blasting—for terrain leveling, bridge building, diversion and access tunnels, and spillway raises—to prepare for the concrete pouring that started in the spring of 1960.

Everything about this project, even the grand remoteness of the site, is of such magnitude as to be almost majestic. In the first place, the job is probably the biggest one going on in the world today. The contract for $107,955,122 was the largest construction contract ever let by the U. S. Bureau of Reclamation, which has let some whoppers. And the prime con-

*Deceased

**NAVAJOS: Much of the dam and reservoir area was on the Navajo Reservation. A special agreement was made with the Indians, and approved by the Bureau of Indian Affairs, to move the Navajos to suitable land in Utah.**

tractor, Merritt-Chapman & Scott of New York City, one of the big and diversified firms in the nation, observed its 100th anniversary in 1960; it is one of the revered veterans of construction.

Located in lonely Navajo country on the northern border of Arizona near the spanking-new town of Page, the dam is the key to a gigantic program designed to control the upper basin of the Colorado River and to generate hydroelectric power and develop a modern recreational area in a region that had been as primeval as the Land of Nod.

The dam is 15 miles upstream from Lees Ferry and 12 river miles downstream from the Arizona-Utah state line; it is 370 miles up the river from Hoover Dam, which spans the lower basin. The concrete gravity arch type of structure will rise 573 ft. above the river bed and 707 ft. above the lowest point in the foundation. The crest length will be 1,500 ft. and the crest width 35 ft. The base will be 300 ft. wide. The dam will contain 5,409,000 cu. yd. of concrete. For comparison, the renowned Hoover Dam was made of 3,250,000 cu. yd. of concrete; Grand Coulee Dam has 10,500,000 cu. yd.

The eight-unit power plant at Glen Canyon will have a capacity of 900,000 kw. The reservoir will be a dilly. It has been named Powell Lake in honor of Maj. John Wesley Powell, who prowled the region and was almost stunned by the scenery and the potential of this wild old river back in 1869. The lake will be 186 miles long and will finger out into some of the wildest, most scenic and desolate landscape ever glimpsed by Major Powell or anyone else. Someone has called it "God's Disneyland." The reservoir will be developed into a National Recreation Area under the National Park Service, much in the manner of Lake Mead behind Hoover Dam. The Glen Canyon Dam will back clear, blue water to lap at the feet of Rainbow Natural Bridge on the rugged flank of Navajo Mountain near the junction of the Colorado and the San Juan. As a matter of fact, a restraining dam and other facilities must be constructed to protect the much post-carded, but seldom seen, Rainbow Bridge. But the water backing up there will make this scenic wonder accessible to wide-eyed tourists; a short boat trip will take them there. At present, the bridge can be reached only by a slow and tiring pack trip or a long river junket and a 10-mile hike, and the result has been that comparatively few brave souls have stood in awe at the foot of the Rainbow Bridge.

### A New Empire

The overall program is designed to open an empire in the land of long solitude in which even the Navajos have had a hard time eating regularly. The program includes three other major dams and 11 additional projects.

The three other principal structures are Navajo Dam on the San Juan in northwestern New Mexico, 34 miles east of Farmington and 3 miles downstream from where the Los Pinos finds the San Juan; Flaming Gorge Dam on Green River in northeastern Utah; and the Curecanti Unit on the Gunnison River in western Colorado. Hydroelectric power will be generated at Flaming Gorge.

The 11 additional units, known as "participating projects," will be mainly for irrigation. No water from Powell Lake behind Glen Canyon Dam will be used for irrigation. But something more than 132,000 acres of new land will come under irrigation from the other units, and 234,000 acres already under cultivation will get more water.

The long-suffering Navajos, who have been trying to rise above poverty, will enjoy some immediate benefits: Navajo Dam will furnish water for the irrigation of nearly 111,000 acres of land, giving the Indians an opportunity to roll up their sleeves and grow more food; this is not apt to add to the bulge of the national surpluses, for the Navajos will be able to consume more than bumper crops could produce and still not get fat.

Along with the empire-opening facets, one main purpose of the almost unbelievably big program is to carry out more effectively the Colorado River Compact of 1922, which divided the waters of the upper and lower basins. The flow of the river is erratic, varying from 4 to 22 million acre-feet a year at Lees Ferry. In long, dry spells there is not enough mountain water to permit the upper basin to consume its allotment and at the same time make the required deliveries to the lower basin, all the way into Mexico which wets its whistle out of the Colorado. So the idea of the storage reser-

voirs upstream is to catch and hold water when flows are high, for use when needed, thus giving a regularity to the river that nature didn't provide.

All of this has been authorized by Congress and the money stacked in a big pile. The total cost will run $760,000,000, the largest expenditure ever authorized for a Bureau of Reclamation development at one time. As time passes, users of water and power will foot the bill.

### Indian Treaty

The Glen Canyon Dam required a treaty with the Indians. Much of the dam vicinity and reservoir area were on the Navajo Reservation. Reclamation powwowed with the Navajos and worked out an agreement under which the Indians received land in nearby Utah for that needed in Arizona for Glen Canyon.

Before the project started, if a man had owned the land he would have been happy to have given it back to the Indians. Nothing except Navajo hogans were near the dam site. There were no roads or communications and no place for anyone to live. Kanab, Utah, was 76 miles away but there was little except rough and roadless terrain between Kanab and Glen Canyon. The site is in Coconino County, of which Flagstaff is the seat; Flagstaff is 135 miles and across the Painted Desert away. Flagstaff and Marysvale, Utah, which is 190 miles away, are the nearest railheads. From the dam it is 300 miles to Phoenix and 384 miles to Salt Lake City.

Glen Canyon, so named because early explorers noticed small glens of oaks, is a gorge 176 miles long between Lees Ferry and the lower end of Cataract Canyon about 14 miles above Hite, Utah. Through most of the canyon the river is confined by massive sandstone walls rising straight up as much as 1,200 ft. Back from the river the land is one of broad, cliff-edged mesas, all looking sunbaked and lonely. Indian writings and pictures on sections of the canyon walls have been identified as of the twelfth and thirteenth centuries, quite a while before Columbus made a name for himself.

The climate is excellent for construction work. Snowfall is about 4 in. a winter and total annual precipitation is 6 in. A man can get up a sweat in the summer, with the temperatures steaming up to as high as 114 degrees. About the coldest temperature recorded there was 2 degrees above zero.

### Preliminary Construction

Work started on July 1, 1956, with the assignment of Bureau of Reclamation personnel to a temporary office in Kanab. The first essential of the project was the building of temporary

**ANCIENT PETROGLYPHS: Indian writings were found on sections of the canyon wall 13 miles upstream from the dam site. Available information indicates that these carvings were made in the twelfth and thirteenth centuries.**

roads across the desert to both sides of the river. When one was on one side of the canyon at the dam site, he was about 1,000 ft. from the other side, but it required a 190-mile trip by car to get over there. Temporary airstrips were built on each side of the river for access to the project and also so that engineers, surveyors, and prospective bidders could get across and do their figuring.

Everywhere there were big things to do. First, though, there had to be roads to the place, a town for workmen and their families, and the river had to be diverted so that the work of notching the canyon for the dam could proceed. The first major work started in October, 1956, when Mountain States Construction Company of Denver was given a $2,452,340 contract to drive the west diversion tunnel. Cooperating with the States of Arizona and Utah, the Bureaus of Reclamation and Public Roads contracted for a permanent road, Alternate U. S. 89, from Bitter Springs, Arizona, through the desert, buttes, and bluffs to the dam site and from there to Kanab.

On December 19, 1956, Reclamation gave a $4,139,277 contract to Judson Pacific-Murphy Corporation and Peter Kiewit Sons' Company to construct a steel arch bridge across the river just below the dam site, joining the new highway from Bitter Springs to Kanab. This bridge was dedicated on February 20, 1959. The spectacular rim-to-rim structure is the highest and second-longest steel arch bridge in the nation; its 1,028-ft. arch stands 700 ft. above the river. The deck is 1,271 ft. long and the roadway is 30 ft. wide and is paralleled by 4-ft. walkways.

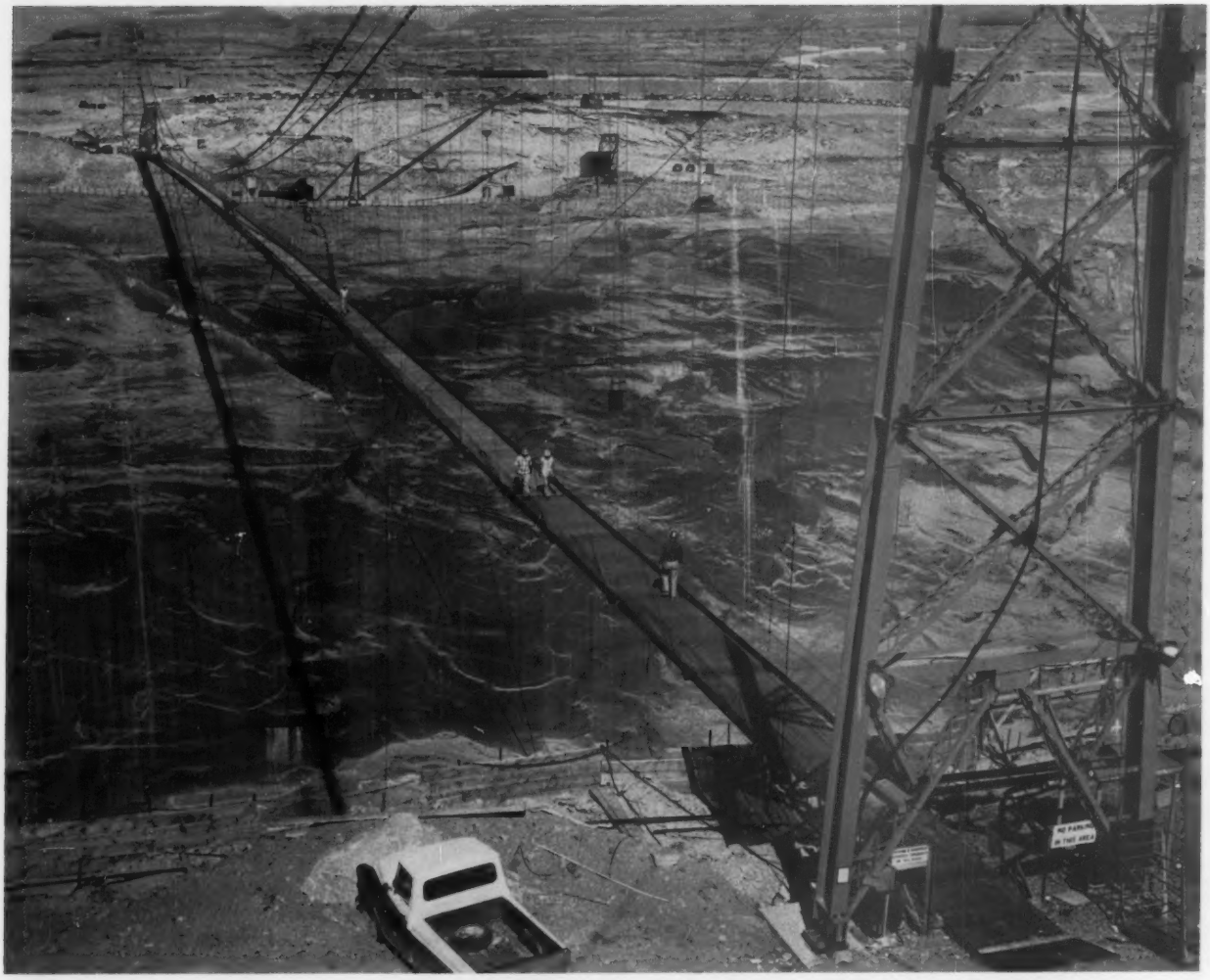
The prime contract with Merritt-Chapman & Scott was let on April 29, 1957. Getting set for a six-year job called for a vast complex of facilities—offices, shops, warehouses, living quarters, power, fuel and water installations, communications, bringing in the outsize equipment needed for such a job. All of this ran into the millions.

### Geology

Drilling and blasting, which were already in progress in the west diversion tunnel and at the bridge, soon started all over the place. Although blasting jobs varied somewhat as to method, the main formations were fairly consistent. This plateau province is an area of almost horizontal sedimentary rocks that have been heaved up without much disturbance of layers. The keyways and foundation of the dam are in Jurassic Navajo sandstone. Buff to red in color, it is massive and highly cross-bedded. The stone is medium- to fine-grained. It is made up largely of white and pink quartz grains with scattered grains of other minerals. Some of the sandstone on and near the surface is pretty badly weathered.

This showed up particularly bad in the west wall when excavation for the skewbacks, or concrete foundations, for the highway bridge started. Because of the condition of the rock, the skewbacks had to be enlarged, necessi-

**THE TOWN OF PAGE: The new town of Page, created to meet the needs of the workers, appeared almost overnight. It has all the facilities found in any modern community and is about 2 miles from the dam.**



**SHORT CUT: To facilitate the movement of workmen and light supplies from one side of the canyon to the other a 1,280-ft. suspension footbridge was built at a cost of $200,000. A tenderfoot gets quite a thrill on his first crossing.**

tating the removal of an additional 9,500 cu. yd. of material.

### Drilling and Blasting

The skewback work was spectacular blasting. At the start, it was difficult to effect a toehold in the canyon walls. The drilling was with regular jackhammers mounted on quarry bars; this was found to be more effective than jib drills from a platform. The men were suspended in bosun's chairs, and it looked as if they were clinging to the cliff for dear life. Actually, the work was not extremely hazardous. Light charges of explosives were used to avoid disturbing adjacent rock.

Considerable blasting was required for the installation of plant facilities such as cableway tail towers, and the building of roads. At least 1,500,000 cu. yd. of rock was blasted out in this phase. Every visitor can see one unusual piece of evidence of this blasting. On the west side of the river slightly upstream from the highway bridge stands a reddish butte which is a famous landmark because it is shaped something like a beehive; it even has a small cave in about the position of the entrance of a beehive. It was a little too close to the river to leave room for a cableway tail tower and other necessary installations, and about one-fourth of it had to be blasted off. Now the beehive is a little whopper-jawed.

An access tunnel to the location of the powerhouse just below the dam site was blasted out. It is 20 ft. in diameter and 2 miles long. About 185,000 yd. of material was excavated. The tunnel enters the wall of the canyon below the dam site and follows the configuration of the canyon wall; it emerges at the river level just below the powerhouse location. During construction it is used as an access route into the canyon and the vicinity of the dam foundation; however, its use is restricted, for there's not much parking space down there. When the dam is complete, the tunnel will be the only vehicular route to the powerhouse. It is wide enough for two-way traffic. Some 700 ft. has a 2% grade and the rest rises at a slope of 8%. Every 500 ft. a ventilation and mucking adit was punched. Muck was dumped out these adits and tumbled into the river.

**WITH THE GREATEST OF EASE: A heavy-duty Euclid is handled with the greatest of ease by the 25-ton-capacity cableway built to get large equipment down into "the hole." The cableway was also used to transport equipment across the canyon.**

Frazier-Davis Company of St. Louis drove the tunnel. W. W. Clyde & Company of Springville, Utah, had the contract for surfacing the floor.

### Diversion Tunnels

At the start, the big hurry was to drive the 2,740-ft. west diversion tunnel so the river could be turned from the dam site as early as possible. Mountain States Construction Company subcontracted the drilling and blasting to Northwood, Inc., of Vancouver and the mucking to Theo Wood Construction Company of Salt Lake City. Drilling was from a jumbo with platforms which could be raised to pass the mucking machines. It was mounted on pneumatic tires rather than on a truck. The jumbo's four decks, each mounting from two to five drills, covered the full face. Usually, 15 drills were used in drilling the 3½-in. blast holes. Something of a pyramid pattern was used in placing the holes so that the main force was to the center. The cut holes in the center were 18 ft. deep and the other holes 16 ft.

Throwaway bits made by Western Rock Bit Company were used. A bit was good for about 48 ft., or three rounds.

From 200 to 250 holes were loaded for each round. Loading of the 40% strength dynamite was at the ratio of ¾ lb. of explosives to the cu. yd. of material in the solid. Electric delay caps, periods 1 to 8, were used; the round was hooked up in something of a parallel circuit and fired with a blasting machine. About 600 cu. yd. of material was pulled to the round. The big tunnel—1,818 ft. of it 43 ft. 6 in. in diameter and the rest of it 46 ft. 6 in. —was advanced an average of 13 ft. a day.

Mucking was in trucks which hauled to waste dumps in the canyon bottom, and the material stockpiled for use in building roads and cofferdams. Lining of the tunnel with concrete was done by Merritt-Chapman & Scott.

Frazier-Davis drove the east diversion in much the same way. It is just short of 3,000 ft. long and is 34 ft. higher in elevation than the west diversion. Therefore, the west tunnel turned the river until spring runoff raised it to the level of the east diversion.

Northwood, Inc., drove the spillway raises, one on each side. Entrances of these 50-ft.-diameter tunnels are about 600 ft. upstream from the dam. They descend at an angle of 55 degrees and end at junctions with the diversion tunnels at about the halfway mark of the diversions. Later the upper ends of the diversions will be plugged and the lower ends will become a part of the spillway system.

### Pilot Shaft

A pilot shaft 7 by 14 ft. was first driven and equipped with a manway 6 by 7 ft.; the manway housed the air and water lines and also some of the equipment. Blast holes for the shaft were drilled from a platform on top of the manway. Atlas Copco stopers were used to drill the 6-ft. holes, which were loaded at a ratio of 2 lb. of explosives to the cu. yd. of material in the solid. Shaft advancement was 8 ft. per day. Muck was removed by gravity into an automatic chute at which S7 Euclid trucks loaded and hauled to the waste area.

With the shaft complete, drilling and blasting started at the top on the full face of the spillway raise. A Gardner-Denver 900 rotary compressor supplied air for the drills. Ventilation was with a Joy 30-hp. fan. Gardner-Denver and Ingersoll-Rand drills, mounted on crawlers, were used in drilling the 12-ft. holes on 4-ft. centers. Throwaway bits by Western Rock Bit were used,

and each bit was good for about 80 ft. of hole. Holes were loaded with bag powder. Blasted material was removed through the pilot shaft.

A rock pillar was left in the spillway opening to help support the roof until supports were in place. What are believed to be the largest steel supports ever rolled were installed in the openings. The top of the tunnel flares into a parabolic curve, necessitating steel settings 115 ft. long. The manufacturer, Commercial Shearing and Stamping Company, bent the huge settings for the tunnel; 32 steel sets were installed.

The pilot shaft, no longer needed, will be plugged.

The sculpturing of the keyways for the dam was perhaps more exacting, and exciting, than the tunnel work. These deep grooves in the towering walls were shot to line and grade all the way down; they don't go straight down but are cut back deeper at the top. This slope was staked all the way down for the blasting operation.

The keyways and the foundations for the dam and powerhouse required the blasting of more than 3,150,000 cu. yd. of material, about 2,182,000 yd. of it rock and the remainder common matter.

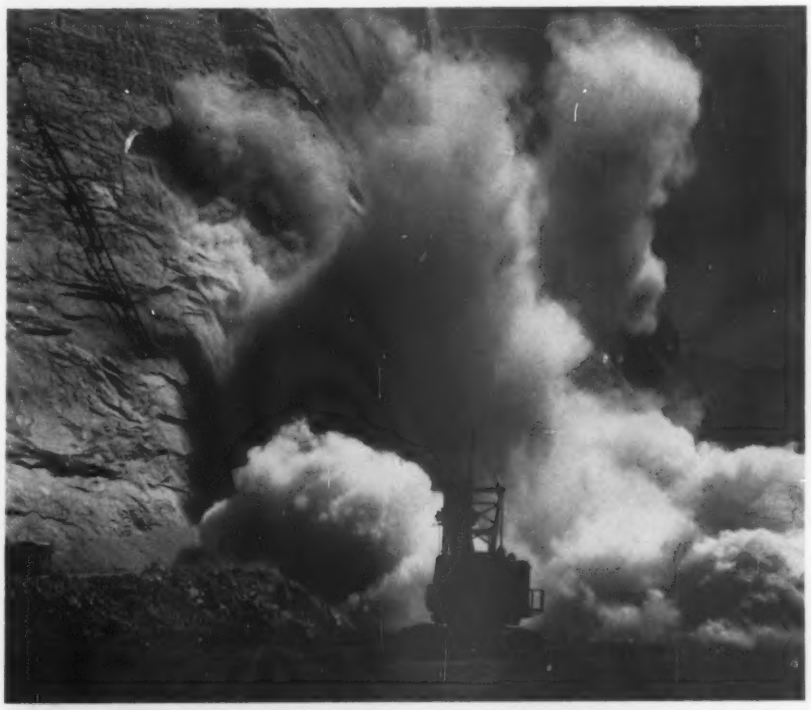
The keyways were brought down by a shelf system of blasting and mucking. Gardner-Denver 123 Air Tracs were used in drilling 3¼-in. holes. Jackhammers were also used and they drilled 2½-in. holes. Liddicoat throwaway bits were effective; the rock was fairly soft but highly abrasive. Brunner-Lay 700-thread steel was used. Air for drilling came from compressor stations on top.

### Blasting Data

Depth and placement of blast holes varied with the ground and the shape of the keyway. As a rule, holes were from 2 to 24 ft. deep. A round ranged from 30 to 50 rows of holes, with the holes 4 to 12 ft. apart. Depending on conditions, the number of holes in a round usually were from 50 to 450, but on up to 1,600. In many places, line holes were drilled 12 in. apart 16 ft. deep next to the wall. The line holes were lightly loaded, sometimes with only Primacord,* but usually with car-

*Reg. U. S. Pat. Off. by The Ensign-Bickford Company

**DRILLING: Sinking the drill holes for the keyways and the foundations for the dam was a big job because more than 3,150,000 cu. yd. of material, about two-thirds of which was rock, had to be blasted. Drilling patterns were adjusted to meet varying conditions.**



**A BLAST IN THE KEYWAY: The keyways were brought down by a shelf system of blasting, and depth and placement of holes varied with the ground and shape of the keyway. The shovel in the foreground was at a safe distance from the blast.**

tridges of 1¼ by 8-in. 40% dynamite placed 2 to 3 ft. apart in the hole with dirt stemming between.

Holes were loaded on a ratio of ⅝ lb. of explosives to the cu. yd. of material in the solid. As a general rule, the hole was primed with a cartridge of 40% dynamite; then from 3 to 12½ lb. of bag powder; then another cartridge of 40%; and, lastly, more bag powder. Holes were stemmed to the collar with drill cuttings. MS delays in periods from 0 to 10 were used, with the line, or wall, holes going last.

With this type of blasting, modified to meet varying conditions, the wall was kept clean, and shattering and cracking were held to a minimum.

The blasted material was loaded with power shovels into International Harvester Payhaulers and was used in building and repairing roads in the plant area. With the haulage road graveled, packed, and watered, the Payhaulers were used until the road reached a 23% grade. From then on, the blasted material was dozed and shoveled over the canyon wall where it rattled into the river bed; down there it was dozed, bladed or hauled to waste dumps for use on haul roads and in coffers.

With necessary changes almost round by round, the blasting pattern continued down to bedrock. The foundation of the powerhouse was blasted out so that it was left in a series of benches, like steps to a post office.

Foundation and grouting tunnels were driven in the keyways as they were excavated. Three were driven 250 to 350 ft. deep in each keyway. Foundation tunnels were 6 ft. 4 in. wide and 8 ft. 4 in. high. Wagon drills were used to line-drill the outline holes, which were on 2-in. centers and 12 ft. deep. These line holes were not loaded. A burn-cut pattern with a 5-hole center group was used. Blast holes, 20 in. apart across the face and 2 ft. apart up and down, were 6 ft. deep. The holes were primed and loaded to the collar with 30% extra dynamite. Blasted material was removed in manually operated cars on a narrow-gauge track. With the use of electric hoists secured to Sullivan pins anchored in the roof, muck cars were lifted from the track for passing in the tunnel.

High scalers had plenty of work in the awesome keyways, ridding the walls of loose rock. When exposed to weather, the rock slacked quite a bit and considerable rescaling was necessary.

In some places, mesh wire was anchored to prevent the danger of falling rock. The worst rock spalling was on the west bank. Great numbers of expansion shell-type rock bolts were used. Bolts were from ½ to 1½ in. in diameter and as much as 20 ft. long. Not only were bolts needed in the keyways but also in the diversion tunnels, the spillway raises, and in the powerhouse access tunnel.

Another drilling and blasting chore that would be pretty big on a lesser project was the exacavation of a bench for the batch plant which mixes the concrete for the dam and powerhouse. It is on the west bank slightly upstream from the keyway. The bench is 190 ft. below the top of the canyon. The blasting of a section of the canyon wall for this bench was expensive and took a great deal of time, but it will pay off during the pouring because it makes possible an all-downgrade delivery of cement and aggregates.

**CANYON FLOOR: A 4-yd. Lima dragline removes material from the center of the canyon floor in getting down to bedrock for the dam's foundations.**

### Concrete Work

The mixing and pouring will last almost four years. The mixing plant is one of the biggest, if not the very biggest, ever built. A good source of aggregate was found 5½ miles from the dam site on Wahweap Creek, a tributary of the Colorado. This was de-

**HIGH SCALERS: Making the drill holes for the blasting of the bridge skewbacks was a job for the high scalers. Despite the hazards of the work, the company has maintained an excellent safety record.**

veloped and an aggregate separation plant installed near the quarry. Aggregate is recovered by dragline and is moved from quarry to plant by conveyor and from plant to dam site by bottom-dump trucks over a road with a maximum grade of 1½%. Water for the concrete work comes from wells drilled by the prime contractor.

The fully automatic Noble mixing plant, equipped with six T. L. Smith 4-yd. mixers, has a top capacity of 480 cu. yd. of concrete an hour. Since the mix must be kept within the specified range of 40 to 50 degrees during placement, and since coolant is necessary to the blocks of mass concrete, a 600-ton-per-hour refrigerating system was installed.

The concrete is being placed with two 50-ton cableways with traveling head and tail towers. The cables, perhaps the largest ever made, are 4-in. lock coils; they were manufactured by United States Steel.

### Suspension Footbridge

Because of the remoteness of the site, the dizzy heights of the canyon walls, the bigness of the project, facilities and equipment have been more of a complex problem than on most construction jobs. Self-sufficiency has been the order of the day. Before the highway bridge was completed there had to be a way to get workmen across the canyon without too much delay. Therefore, Merritt-Chapman & Scott had a 1,280-ft. suspension footbridge constructed across the canyon at a cost of $200,000. Kiewit and Judson Pacific-Murphy, contractors for the highway span, and J. A. Roebling's Sons Corp. built the footbridge. The handrails are of cables and the walkway of wire mesh. A good way to acquire a revealing feel of the mightiness of the canyon and the things that men are doing here is to stroll out halfway across the footbridge, take a manly grasp on the handrail and lower your eyes on the scenery 1,000 ft. below. The feeling is intensified if, as often happens, a workman comes put-put-putting across on a motor scooter, creating a vibration that makes the tenderfoot wish he hadn't tried it.

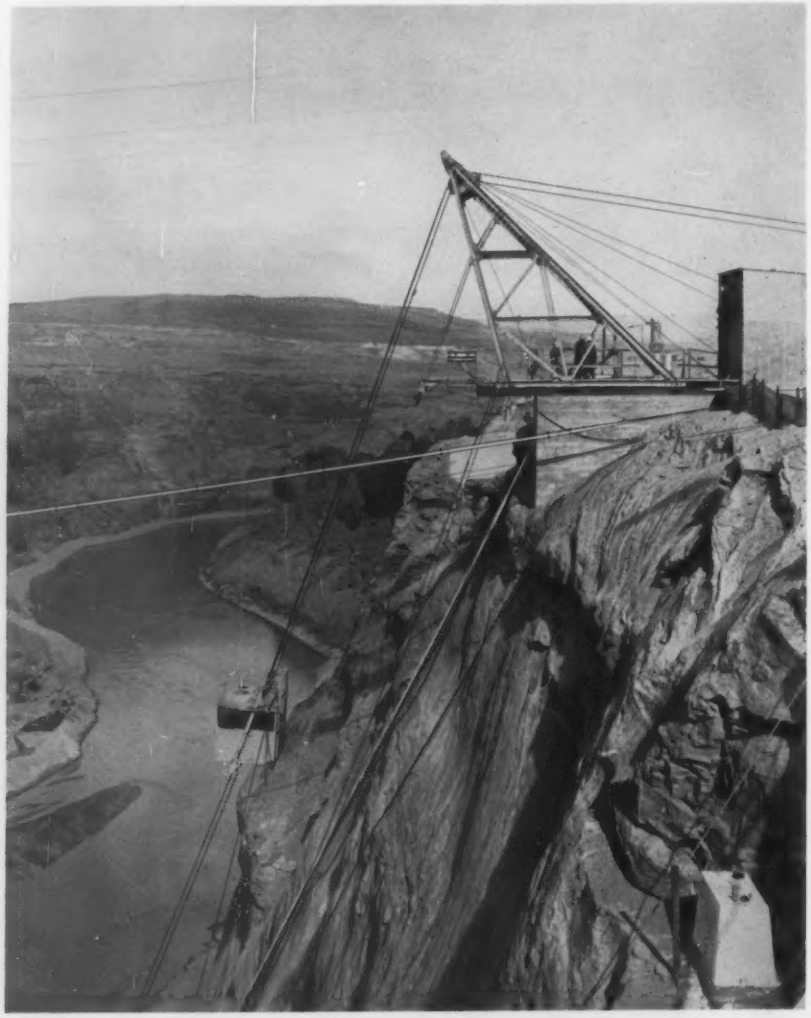
Early in the work, the prime contractor installed a 25-ton-capacity cableway for servicing construction of

the diversion tunnels and other work down in "the hole." Much of the equipment used in the bottom, including heavy trucks, scrapers, shovels, cranes, and tractors, was lowered on the cableway. The transporting of men and light materials between the rim and the lower regions is accomplished efficiently by several man elevators over the rim; they are known as monkey slides.

### Equipment

Nearly every kind of modern equipment has been used on this job and much of it is still in use. Among major items of equipment used by Merritt-Chapman & Scott were International Harvester Payhaulers, trucks and tractors, the tractors ranging in size up to TD-24; Caterpillar tractors; Lima cranes; Manitowoc cranes; Marion shovels and truck cranes; Lorain truck cranes; Mack tractors and trucks, including transit-mix; Cook Brothers bottom-dumps; Fruehauf trucks; Euclid bottom-dumps; Wayne buses; Double Pumpcrete machines; Koehring Dumptors; Joy stationary and portable compressors; Gardner-Denver and Ingersoll-Rand compressors.

Probably the best-equipped machine and maintenance shops on any recent construction job have been operated from the first, with nearly all repairs and modifications being made on the job. Because of the great distance to parts and replacements, an inventory of parts valued at around half a million dollars has been kept on hand at the plant by Merritt-Chapman & Scott and by Cummins and International Harvester; Cummins and IH, both with much equipment on the job, sold parts on an over-the-counter basis, and still do.



THE MONKEY SLIDE: Men were transported between the rim and the lower regions of the canyon by several man elevators. These efficient units soon became known as monkey slides by the men who used them.

### Communications System

Unless there were some grizzled Navajos around who remembered how to puff smoke signals, there were no communications in this little-known land at the start. Few, if any other, construction jobs ever developed a more impressive or efficient system of telephone and radio communication as at Glen Canyon. Mountain States Telephone and Telegraph cooperated in bringing in lines from the outside, connecting to the construction camp system and installing an exchange at Page. Merritt-Chapman & Scott subcontracted the electrical end of communications to Morgan Electric Company of Seattle.

When radio was first set up at the site, it wasn't very effective because it wouldn't carry between the top and bottom of the canyon, whereupon a 60-ft. antenna was installed on top of a nearby hill. Now every operation is connected by telephone or radio, or both. Many of the vehicles are equipped with two-way radio. In quite a few instances, Teletalks are used instead of regular telephone. Communications were developed to the fine point where spotters were in communication with high-scaling hoist operators. The offices of Merritt-Chapman & Scott can effect immediate communication with every place where men are working.

### Power Supply

The prime contractor generates and distributes electric power for the job, the Government needs, and the town of Page. Westinghouse generators powered by Fairbanks Morse engines and English Electric generator units are used. Power is distributed throughout the construction project on a grid system. Because of the danger of violent electrical storms, the power system is equipped with numerous arresters to guard against lightning. The powerhouse, a 70 by 180-ft. Armco

steel building, was air-conditioned because high temperatures cut down the efficiency of the English Electric engines which draw air from inside the building. The system has been enlarged as more power was needed.

Water, aside from that going from wells to the construction job, is pumped from the Colorado; it is filtered, treated, and stored in a 3,000,000-gal. reservoir. From there it is pumped into a 150,000-gal. elevated tank which feeds into the distribution system. A sewerage system was installed.

### The Town of Page

Page is one of the newest towns in the nation. It sprang up almost overnight on wasteland and now has all the facilities of a municipality—stores, shops, restaurants, bowling alleys, supermarket, top-quality motels, service stations, churches, schools, a golf course.

The Bureau of Reclamation put up many temporary and permanent residences, warehouses, municipal office buildings, administrative buildings, and quarters for police and fire departments. Page has a post office, telephone building, and a bank. It is a complete town and a clean, attractive one, and, among other things, it has one of the most spectacular views in Arizona—out in the direction of Glen Canyon 2 miles away.

The Page population has climbed past 5,000. There are still many trailers around, but the town, named for a one-time commissioner of the Bureau of Reclamation, is taking on a look of permanence. When the construction is finished, Page will be the principal municipality of the recreational area; moreover, with water and with power, this one-time desolate spot may become a center of industry.

Much of the credit and excellent planning of the town goes to the Bureau of Reclamation, which has had more experience in handling tremendous projects in out-of-the-way places than any other agency or organization in the nation, if not the world. Grant Bloodgood, assistant commissioner and chief engineer of the Bureau, with offices in Denver, was the contracting officer and responsible for designs, specifications, and construction. Frank Clinton is the regional director of the

**AT THE HEADING:** The jumbo used in the diversion tunnels was mounted on pneumatic tires, for easy mobility. Drill platforms could be raised to allow the mucking machines to pass under the jumbo to reach the heading.

**INLET PORTAL:** The inspector standing in the inlet of the upper portal of the left diversion tunnel is dwarfed by the size of the tunnel. Excavation of this and the other diversion tunnel was a major drilling and blasting job.

Bureau. L. F. Wylie, who has had wide experience with the Bureau, is the project construction engineer. The Bureau has maintained a considerable staff on the project.

Merritt-Chapman & Scott has also contributed in a major way to Page. The prime contractor has erected residences and dormitories. The company also built a 25-bed hospital for use of Page residents; it is modern in every respect and well staffed.

The elements of camp life have virtually disappeared from Page, which has more, newer, and better services than the average Western town its size.

### M-C & S Centennial Year

Merritt-Chapman & Scott never does anything halfway. It is an old outfit that is as modern as tomorrow. It started back in 1860, when Capt. Israel J. Merritt opened for business with a single marine salvage schooner. In 1897, Merritt merged with the Chapman Derrick & Wrecking Company, headed by William E. Chapman. The business expanded rapidly and in 1922 the Merritt-Chapman organization joined with the T. A. Scott Company. Merritt, Chapman, and Scott were imbued with the pioneering urge. They had big dreams and the courage and fortitude to make them come true. In 1949, Louis E. Wolfson, now chairman of the board, joined the company and launched it on a new era of pioneering. It has undergone wide, successful expansion in the past decade.

Almost as well known as the Black Horse flag that flies on a pole at every M-C & S job is the slogan "You Name It, We Build It!", and this is no exaggeration; the company is in construction, marine salvage and derrick operations, shipbuilding, chemicals, paints, metallurgical products, fuel, building materials. Not long ago, New York Shipbuilding Corporation, a part of Merritt-Chapman & Scott, completed construction of the *Savannah*, the world's first nuclear-powered merchant vessel.

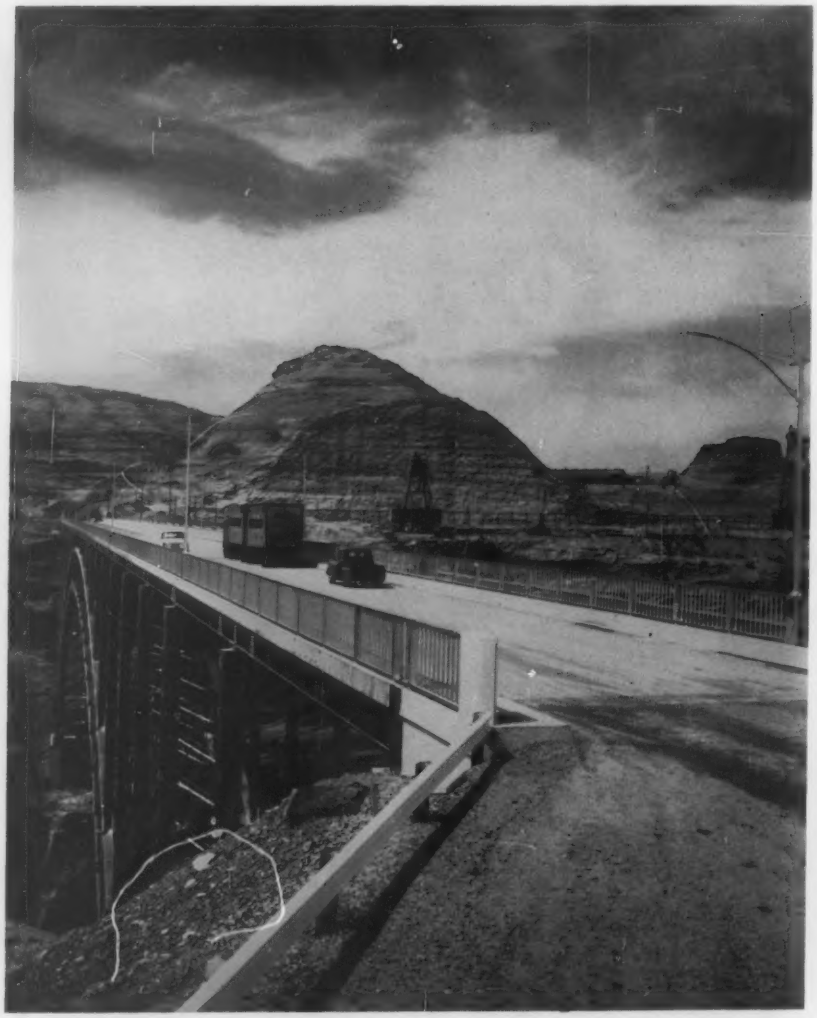
In the past, the enormous reclamation jobs have been handled by groups of contractors, and it is very probable that Glen Canyon is the biggest job ever tackled by a single company; it is one of the few projects that ever called for the assembling of a plant, facilities, and equipment worth around $10,000,000. The project, due to be completed in March of 1964, is on schedule, and there seems a good chance that the construction will be finished in 1963.

A. R. Bacon is the project manager; John Heckart, general superintendent; Col. A. H. Griffin, project engineer; Ken Hayes, excavation superintendent; Tex Battenfield, general foreman in charge of excavation.

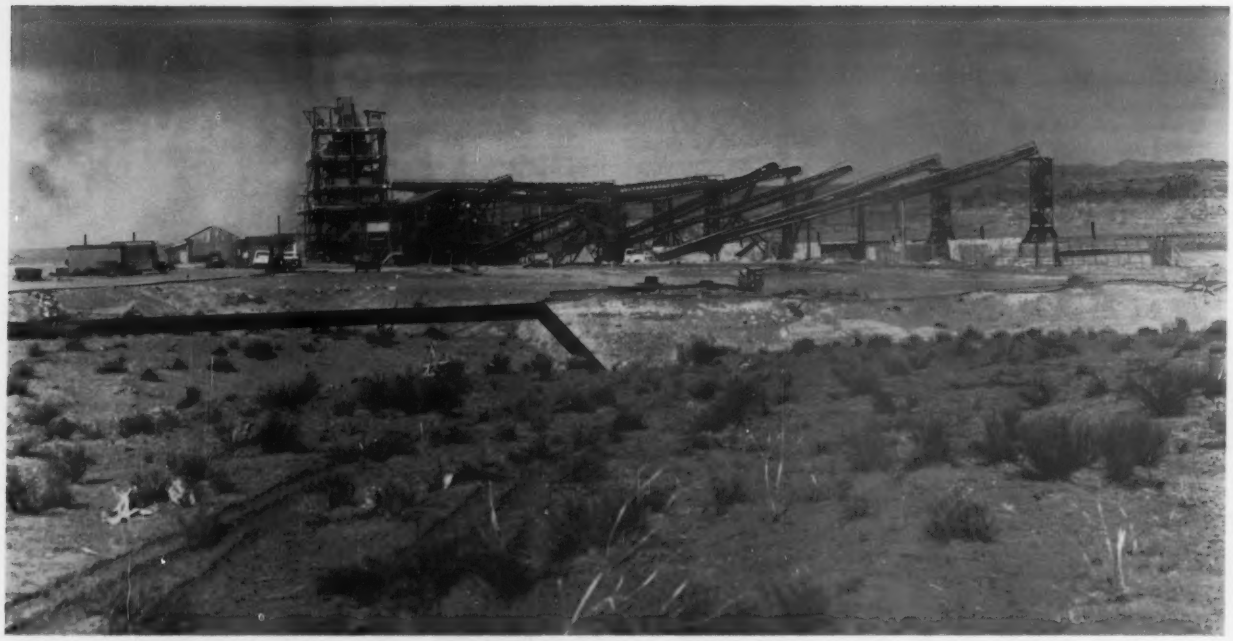
On this project, the prime contractor has had up to 1,250 men working at one time, around 100 of them Navajos; this doesn't count Bureau of Reclamation personnel or the crews of subcontractors. During the concrete phase, Merritt-Chapman & Scott will use between 550 and 600 workmen.

### Safety Record

Despite the natural hazards of this work along the top and in the yawning gorge of the river, the company has maintained an exceptionally good safety record. Accident frequency stands at 13, compared to the national average of 35, and the average on Bureau of Reclamation projects is slightly more than 30. Recently the State of Arizona gave the prime contractor a special award—the first ever presented by the State—for its safety program and record at Glen Canyon. The company has a full-time safety director, and the Bureau has two safety engineers on the job.



**GLEN CANYON BRIDGE: Standing 700 ft. above the river, the Glen Canyon Bridge, with its 1,028-ft. arch extending from rim to rim, is the highest and second-longest steel arch bridge built to date in the United States.**



**AGGREGATE PLANT: A good source of aggregate was found about 5½ miles from the dam site, and an aggregate plant was installed near the quarry. The aggregate is moved from the quarry to the plant by conveyor.**

At the beginning of each shift every Monday, there are 10-minute "tool box" safety meetings. In addition, there are full-dress monthly sessions at which job hazards and safety standards are discussed in full detail.

There have been quite a few "firsts" and "biggests" at Glen Canyon out there in the one-time lonesome country. It is a graphic example of how American industry, with its pioneering spirit, know-how, engineering skill, and marvelous equipment, can manhandle wild rivers and convert butte-studded waste into productivity.

**MAJESTIC GRANDEUR: A cowboy and his horse gaze over the vast changes and the bustling activity that Merritt-Chapman & Scott has brought to the majestic grandeur of the Arizona landscape.**

# Mining Lithium at Kings Mountain In North Carolina

## Lithium, little used a few years ago, is now finding an ever-widening range of applications, and Foote Mineral Company is helping to meet the increasing demand

NEIL O. JOHNSON*

THE nation's major supply of lithium, which is growing in importance, is being blasted out of the ground near historic Kings Mountain in North Carolina. The Foote Mineral Company, an 85-year-old concern that long has been a leader in light metals, in chemicals, and in research, has an open-pit mine and a modern processing plant there.

The drilling and blasting are of peculiar interest because the pit is near residential areas, and vibration must be held to a minimum; moreover, the blasting pattern has been developed to control the throw of the material and to improve fragmentation. The operation is an engaging example of selective mining, that is, dividing ore and waste in the pit. Mineral-bearing ore lies in bodies separated by wall rock. This "waste" must be removed to get rid of it, but it also contains commercial products. On the benches in the pit, the strips of barren material are taken first to prevent dilution with the ore. As in nearly all mines, there is

*Manager
Foote Mineral Company
Kings Mountain, North Carolina

THE MINE: Located in a region containing the richest known deposits of lithium ore in the world, Foote Mineral Company extracts the valuable material from the earth and ships it for further processing to its Sunbright, Virginia, chemical plant.

some mingling of ore and waste, but the selective mining is efficient.

### Historic Site

To a great extent, the Foote enterprise is making history where there has already been a lot of history. Lithium is comparatively new as a highly useful element; the technical know-how of what it will do and the most efficient way to recover and process it have been developed in comparatively recent times. Lithium is the lightest metal known to man, weighing only 33 pounds to the cubic foot.

Lithium was discovered by Johann Arfwedson in 1817, years after Kings Mountain was known the world over as the site of one of the decisive and significant battles in American history. A great many American-history students have the impression that the battle was between American "Mountain Men" and English soldiers, but this is not exactly true. Actually, the mountain men were American Whigs and the English force was made up of American Tories. The only British soldier in the entire battle was the Tory commander, a tempestuous Scotsman, Maj. Patrick Ferguson.

Ferguson developed and held a patent on the first military breech-loading rifle. On October 7, 1780, Ferguson and his men established their lines on top of Kings Mountain, a natural stronghold because of its commanding view of the terrain in all directions.

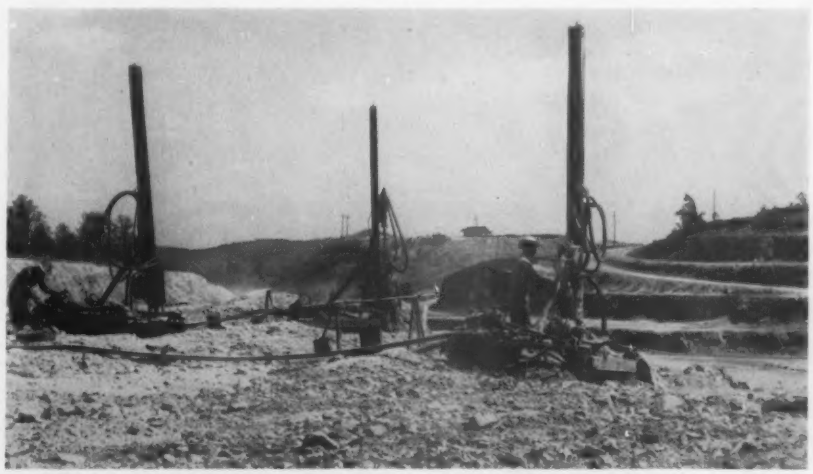
He has been quoted as having said: "We are at the top of Kings Mountain. I am king of this mountain and God Almighty and all the Rebels out of hell cannot drive me from it."

And well, sir, he's still there on top of that mountain.

Because of the threat of invasion by Ferguson, a hastily mustered force of about 1,000 mountain men from the Carolinas, Virginia, and what later became Tennessee hurried across the mountains into the valley of the Catawba, determined to protect their frontier homes. They surrounded Kings Mountain and soon had the Tories in confusion. Seeing that they were in a bad way, the Tories ran up a surrender flag. Ferguson, dashing about the mountain on horseback, clipped down the flag with his sword. He had been wounded and had had several horses shot from under him, but he organized a point-blank charge at the mountain men, who carried deadly muzzle-loading rifles. It was suicidal. Ferguson and most of the men in the charge fell. The commander was buried near where he fell.

**ORE AND WASTE: A dramatic close-up shows pegmatite ore dikes in contact with the darker amphibolite waste rock. Selective mining proved the most efficient method of extracting the lithium ore-bearing material.**

The disaster for the English forced Cornwallis to retreat from Charlotte Town, brought hope to the Whig cause in the South, upset the British timetable, and eventually culminated in the surrender at Yorktown and American independence. A national military park and museum stand in memory of the battle of Kings Mountain. The museum displays, among many other interesting relics, a rare Ferguson rifle, the invention of the English commander who died on top of the mountain. It was the latest thing back in 1780. Down the slope a way,



**DRILLING: Air Trac drills are used for making blast holes in both the ore-bearing material and the waste. Holes 2½ in. in the ore and 3-in. holes in the waste are drilled 24 ft. deep, 4 ft. below grade. In the ore, holes are 6 ft. apart, with the rows on a staggered pattern 5 ft. apart.**

**SELECTIVE MINING: This excellent view of the pit shows selective mining as practiced by Foote Mineral at Kings Mountain. The actual procedure for the removal of rock and ore depends upon the width of the pegmatites. In large ore bodies the surrounding waste is removed, leaving the ore body exposed on three sides to prevent contamination.**

men are producing lithium for today and for tomorrow.

The beautiful little city of Kings Mountain, in the heart of the Carolina industrial Piedmont, didn't come into being until the Southern Railway built through in 1872. Today, the city, which is a textile and mining center, has a population of about 8,000. The historic mountain is in the virtual center of the Lincolnton-Gaffney mineral belt of the Carolinas.

Today, as in the long ago, the Kings Mountain area is contributing to the defense of American independence and well-being, for lithium, lightest of all metals, is definitely a thing of the atomic age. Kings Mountain itself, a land-locked leviathan, forms a panoramic backdrop for the Foote lithium-mining operations. The mountain is only 3 miles from the lithium works.

Lithium-bearing minerals occur mostly in pegmatites, which are holocrystalline rocks of variable grain but usually coarse; their major constituents include minerals typical of igneous rocks. Pegmatites are complicated and create baffling problems of exploration and production.

### Ore Deposits

Pegmatites containing lithium ore minerals are found throughout the world—Europe, Russia, Africa, South America, Canada, and elsewhere. The largest known sources in the United States are the Black Hills of South Dakota and the tin-spodumene belt of the Carolinas, the latter-named being the main one. Here, a narrow, sinuous zone roughly 30 miles long and less than a mile wide, on the average, extends northward from Gaffney, South Carolina, to Lincolnton, North Carolina. The pegmatites occur in weakly metamorphosed sediments; the largest of the pegmatite dikes are those filling the northeasterly trending fractures in the areas of mica and hornblende gneisses and schists. To the southeast of Kings Mountain is the largest known concentration of the pegmatite bodies in the tin-spodumene belt. Several large and closely spaced ore bodies crop out within an area 2 miles long and half a mile wide. The largest of the pegmatites here is over 1,500 ft. long and about 350 ft. wide. This is where Foote Mineral is operating.

Before 1940, operations in the area were confined to small-scale, intermittent tin mining, but then things began to change. Solvay Process Company acquired mining property, built a flotation plant, and began producing spodumene along with feldspar. This operation lasted from 1942 to 1945 and less than 15,000 short tons of spodumene concentrate was turned out. Foote Mineral, a commercial producer of lithium chemicals since 1934, was the principal consumer of the spodumene processed by Solvay. By 1948, the market for lithium chemicals had advanced to the point where Foote felt that it ought to look into a long-term source, and the company bought the Solvay property in October, 1950. Foote installed a new crushing plant and renovated the flotation plant. Since that time, the plant has been rebuilt and expanded at a cost of $3,000,000.

Extensive exploration drilling has been done, furnishing a basis for computing the ore reserve: the present measured ore reserve is 20,746,297 tons averaging 1.53% lithium, and there is an additional indicated reserve of 15,769,075 tons, bringing the total to 36,515,372 tons. And there is a great deal more ore in the area.

### Mining System

Plans for developing and mining Foote Mineral Company's ten-bench, 200-ft.-deep open-pit mine were formulated from data obtained from the first three exploration programs. The present pit has seven benches and an area 1,400 ft. wide by 1,600 ft. long, encompassing approximately 53 acres. Each bench has a 20-ft. face. This is considered a safe working height and permits maximum selectivity and production in mining the ore bodies.

Three benches are mined simultaneously; as one bench nears completion, a new bench is opened up, with the major production coming from the intermediate level. To develop a new bench, a slot wide enough to permit working room is started from the southeast corner of the pit. This slot, driven to the far side of the pit before being widened, cuts across the pegmatite ore bodies and country rock at nearly right angles. Upon completion of the slot, the ore and waste faces are advanced northward separately.

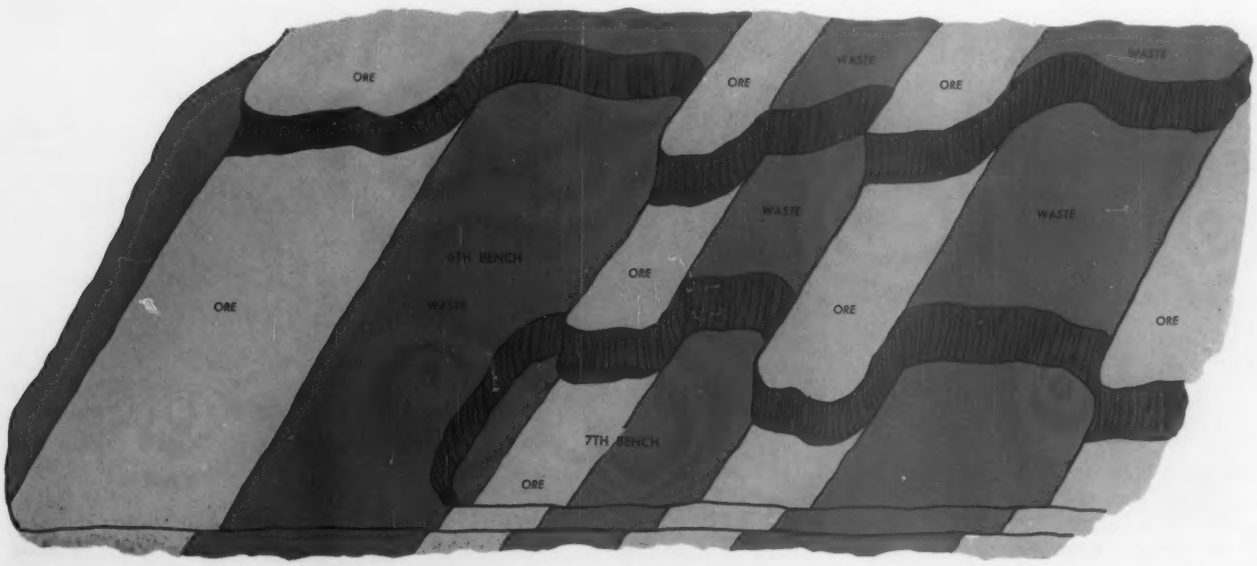
The mining system used depends upon the width of the pegmatites. In large ore bodies, the surrounding waste is removed first; thus the ore is exposed on three sides to prevent contamination. In the medium-size ore bodies, selective mining is against the steep dip, which is generally toward the west. Using this method, the ore can be shot away from the waste, and vice versa, thus reducing the dilution of the ore and ore loss in the waste.

Small pegmatite stringers (less than 10-ft. width) are not considered economically feasible to mine by themselves. However, by including them with the waste which is drilled with a greater burden and spacing, they are broken into large fragments. While loading waste these are cast aside, then by using the dropball they are reduced in size for the ore crusher. As a result, a large percentage of these small ore stringers are separated and recovered as ore.

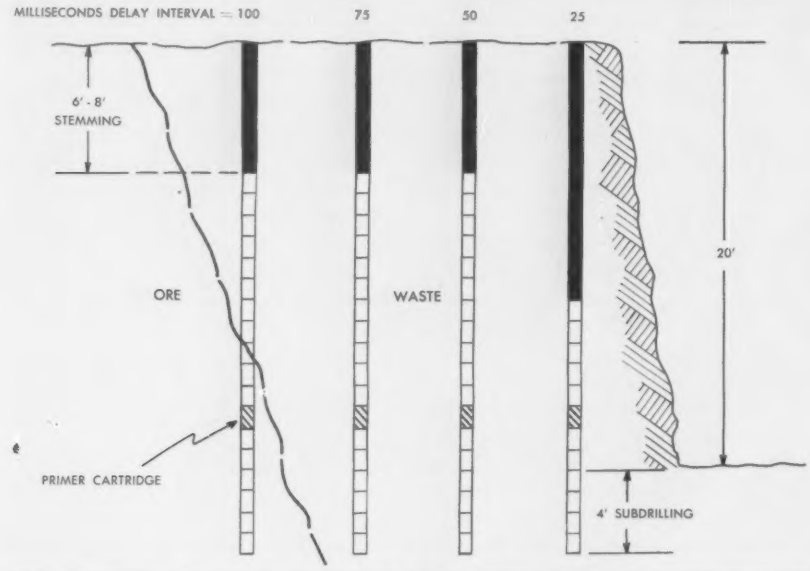
### Drilling and Blasting

Blast holes in ore are 2½ in. in diameter and 24 ft. deep, which is 4 ft. below the grade on the 20-ft. bench. The holes are 6 ft. apart and the rows, which are on a staggered pattern, are 5 ft. apart. From 60 to 80 holes are loaded for a round, and a round never goes more than 125 holes. Because of the nearness of residential areas, the blasts are kept relatively light. A primer charge of six 2 by 12-in. cartridges of Hercules® 60% Extra Dynamite, or equivalent, is placed in the bottom of the hole. The top cartridge is equipped with an MS delay electric blasting cap. The hole is then filled with explosives (dynamite in damp ones and ammonium nitrate prills and Primacord* in dry ones) up to within

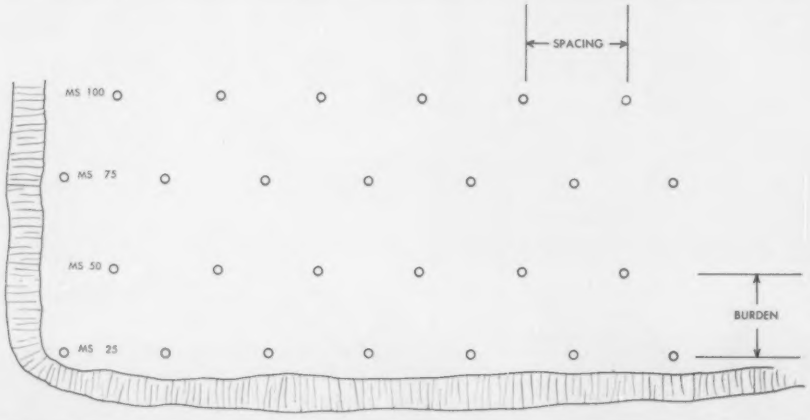
*Reg. U. S. Pat. Off. by The Ensign-Bickford Company




**BENCH DEVELOPMENT: The open-pit mine was developed from data obtained from several exploration programs. The present pit has seven benches, each with a 20-ft. face. Three benches are mined simultaneously, and as one bench nears completion a new one is opened up.**




**LOADING DIAGRAM: A primer charge of six 2 by 12-in. cartridges of Hercules 60% Extra Dynamite, with an MS delay electric blasting cap in the top cartridge, is placed at the bottom of the hole. The hole is then filled with explosive to within 6 to 8 ft. of the top and stemmed.**




**PLAN VIEW: The same basic drill pattern is used in both ore and waste material. However, for the waste area the spacing is increased from 6 ft. to 9 ft. and the staggered rows have a 7-ft. burden instead of 5 ft.**

6 to 8 ft. of the top; then the hole is stemmed to the collar. The stemming minimizes air concussion. MS delays from 25 to 400 are used to reduce vibration, control the throw of the material, and to improve fragmentation. The holes are hooked up and the blast is fired with a conventional type of blasting machine. From 6,000 to 10,000 tons of material is broken with a 60 to 80-hole round.

In waste, the drilling pattern is the same as in ore except that the holes are 3 in. in diameter and are 9 ft. apart in rows 7 ft. apart; loading is the same except the dynamite is in 2½ by 12-in. cartridges and the loading above the primer charge is somewhat lighter because fragmentation is not so important as in the ore. The hookup, delays, and the firing of the shot are the same in waste as in ore.

Results of this system of blasting are satisfactory. There is no secondary blasting. A dropball is used for any necessary secondary breakage.

Blast holes are drilled with Gardner-Denver Air Trac crawlers mounting DH-99 drills. Sectional steel in 8-ft. lengths is used. The 2⅝-in. detachable bits with tungsten carbide inserts drill at the rate of 35 ft. an hour and the 3-in. bits at 25 ft. an hour.

A Gardner-Denver stationary compressor of 1,300-c.f.m. capacity supplies air to the drills through a permanent 6-in. main header which encircles the pit; 4-in. lines from the Victaulic coupled main header are easily moved to any area to be drilled.

### Haulage

There is a great deal of selectivity in loading the ore and waste, the principal division being made in the mine; for this reason the size of the shovels is limited. Ore and waste are loaded into trucks with 38B Bucyrus-Erie shovels equipped with 1½-yd. dippers. A Model 6 Northwest shovel is on standby in the pit. Ore is loaded into 10-ton Euclid trucks for the ½-mile haul to the plant. Waste is loaded into 15- and 20-ton Euclids, which haul from one-half mile to a mile. Approximately one-half of the nonlithia-bearing rock is sold to a commercial stone quarry which operates a crushing and sizing plant near the pit. Except for short sections, haulage roads are kept on a grade of less than 10%.

Caterpillar dozers are used for cleanup around the shovels, some road work, cleanup on dumping areas, and general service around the plant. A motorgrader is used to maintain haul roads and to pull a 2,000-gal. water wagon to wet down the roads during dry weather.

The ore is abrasive and spare buckets are built up regularly. Adapters and box points are used on the buckets; the adapters can be built up two or three times before they are discarded, but box points are replaced nearly every week.

### Processing

The processing for the recovery of lithium and various by-products is an exacting operation. The ore trucks dump into a 26-in. Traylor gyratory crusher which reduces to 6 in. At times it is necessary to remove small amounts of black waste rock; this is done manually on a picking belt after primary crushing.

From the primary, the ore goes to

a 4¼-ft. Symons cone crusher which reduces to under 1½ in. The tertiary section of the crushing plant consists of a 5 by 12-ft. double-deck Tyrock screen, 48-in. spiral classifier, and a 3-ft. Allis-Chalmers Hydro cone crusher.

Minus 1½-in. material from the secondary is split into three sizes on the Tyrock screen. The plus ½ in. is crushed, open stage, to minus ½ and rejoins the minus ½ in. plus ¼ in. The minus ¼-in. rock is washed in the spiral, with the sands going by a common conveyor to the crushed ore stockpile. From there the material goes to the heavy-media process building or to the flotation mill, depending on the production demands.

Crushed ore from the stockpile is conveyed to feed bins over a Merrick Weightometer. It is ground in 5 by 12-ft. Marcy rod mills; then it is classified and separated by conventional flotation methods into the various products.

The spodumene concentrate is filtered in Dorr internal drum filters and dried in a Ruggles Cole-type drier, which is fired by natural gas. Ceramic-grade spodumene is produced from the dry, chemical-grade product by screen sizing and magnetic separation on a Carpco high-intensity roll-type separator.

Rail shipment to Foote's lithium-processing plant at Sunbright, Virginia, is in hopper cars. A 7,400-ft. spur line was constructed recently to connect the plant with the main line of the Southern Railway system. This permits the efficient method of direct loading from plant into rail cars.

### Co-products

In addition to chemical-grade spodumene, Foote's co-products at Kings Mountain include high-grade mica concentrate, ceramic-grade spodumene, and commercial stone. Mica, which is sold to processors, is used in roofing material, paint pigments, wallboard joint cement, plastics, and many other materials. Ceramic-grade spodumene is used in the manufacture of glass, porcelain enamel, ground coats, as a constituent in ceramic body fluxes and glazes, and in low-expansion, heat shock-resistant bodies. Amphibolite mine rock, another of the co-products, is sold to Superior Stone Division of American-Marietta Company for use as commercial stone.

Foote is currently studying other possible products, including beryl, feldspar, and quartz. The largest known domestic source of beryl is in the tin-spodumene belt. There is considerable research in methods of turning beryl concentrates into finished beryllium products. The U. S. Bureau of Mines has a pilot plant on the Foote Kings Mountain property, the objective being to evaluate the technical and economic problems involved in the recovery of beryl from the Kings Mountain ore. Beryllium metal use has grown rapidly in the past ten years, and, like lithium, appears to have an attractive future. The unusual metallurgical and nuclear properties of beryllium indicate that it will find increasing use in nuclear energy and in missile and space vehicles.

### Equipment

The Foote operation at Kings Mountain is modern in every way, with the right tools for getting the job done. Auxiliary mine equipment includes a 1½-ton flatbed truck equipped with grease guns and fuel tank for servicing shovels, trucks, and dozers; another 1½-ton flatbed for servicing drills; and a 1-ton truck especially equipped for hauling powder and for supervisory transportation.

Powder men use a portable compressor to clean blast holes before loading. A portable welding machine in the pit is for shovel repair and miscellaneous welding. Shovel bucket build-up and major repairs are handled in the shop.

The large, permanent shop has three vehicle bays big enough for the shovels; they are equipped with a 38-ft.-span overhead traveling bridge crane with two 5-ton-capacity electric hoists. The crane travels 100 ft. Other major shop equipment includes a 125-ton air-operated hydraulic press, an exhaust system for removal of fumes, two 300-ampere electric welders. The shop has office facilities for maintenance supervision and records.

A service building is equipped with individual lockers and with showers for hourly employes and foremen. It also has a large area which serves as a lunch room and a place to hold meetings, such as safety and training programs. A large warehouse with fenced-in area is used for storing all parts

**BLASTED WASTE MATERIAL: The blasting procedure in the waste sections is to drill 3-in. holes 24 ft. deep, 4 ft. below grade on 9-ft. spacings in rows 7 ft. apart. While fragmentation is not as important as when blasting in the ore, the material is easily handled by the 38B Bucyrus-Erie shovel.**

and supplies needed in the operation.

Foote emphasizes safety in the mine and plant, and during the past several years has received numerous safety awards.

### Quality Control

The laboratory is a busy place. It is operated by the plant chemist and technicians who prepare samples and analyze all incoming ore, outgoing products, and the tailings. Samples are filtered, dried, crushed, and pulverized and, if necessary, screened in the control lab near the mill. Lithia analyses are made in an ultra-modern analytical laboratory. All spodumene samples are calcined to convert the ore to soluble beta-spodumene. The converted ore is digested in acids and diluted to proper concentrations. The alkali metals are analyzed on a Beckman Model B spectrophotometer with flame attachment. Mica determinations are made by specific gravity separation in heavy liquids.

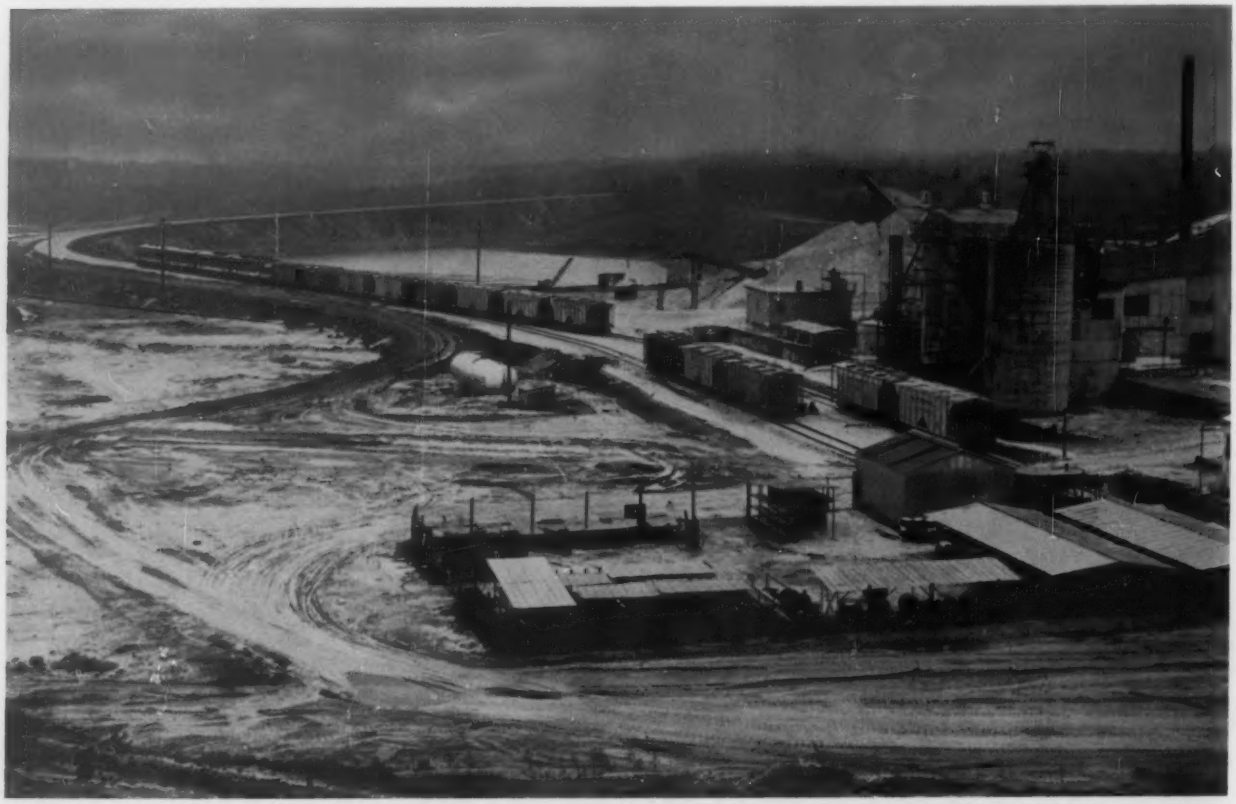
In the plant, all process water is recirculated because the supply of fresh water is limited. The mill tailings effluent is treated with Ferri-Floc and the solids retained behind dams. The decanted water is pumped by barge pumps to a 15,000,000-gal. clarification pond, from which it is pumped to the plant by turbine-type stationary equipment. Fresh creek water, used for make-up, is stored in a 55,000,000-gal. reservoir, which has a stationary pumping station. Boiler and compressor cooling water, and also that used in the office and other service buildings, is bought from the city of Kings Mountain.

Power is furnished by the Duke Power Company. It is transmitted into the plant area at 44,000 volts. One station serves the mine, the other the mill and plant area.

The Foote operation at Kings Mountain is a dramatic example of how American industry can quickly gear itself to produce what is needed and, in the process, create employment and conduct research which leads to more new things, better living, and a more adequate defense to protect what the mountain men were fighting for when they surged out of the valley of the Catawba on that yellowing October day in 1780. Not many years ago lithium production consisted only of laboratory quantities. In 1959, production ran into millions of pounds of lithium hydroxide monohydrate. Reliable forecasters estimate that by 1975 at least 200,000,000 lb. of the monohydrate equivalent will be needed.

Lithium, the lightest of the solid elements, is used as a scavenging agent, an alloying metal, as a catalyst in organic reactions, including polymerization, and in the preparation of organic products. High-purity copper is obtained by the addition of lithium metal in its final stages of smelting. Lithium alloys effectively with many of the common metals, such as lead, aluminum, zinc, copper, magnesium; the beauty of lithium is that it results in a stronger and lighter alloy.

Lithium also combines with a large number of the nonmetallic groups (including the halogens, sulfur, nitrogen, carbon, hydrogen, and other materials)



**ON ITS WAY: The lithium ore leaves Kings Mountain for further processing at the Sunbright, Virginia, plant. The Kings Mountain operation is served by a recently constructed 7,400-ft. spur line that connects with the main line of the Southern Railway.**

to form many inorganic and organic compounds.

### Markets

At present, lithium chemicals have a much wider use than the metal, the most important being the hydroxide, carbonate, and halides. About 30% of all automotive greases contain lithium in the form of stearate; lithium-base greases are all-purpose, being resistant to moisture and effective over a wide temperature range.

The carbonate is used in porcelain, glass, and ceramics; in porcelain enamels for steel and aluminum, lithium reduces viscosity and permits thinner, more fluid coats which can be fired at lower temperatures, and it imparts higher gloss, greater impact strength, and acid resistance. In glass, lithium likewise reduces viscosity, increases strength, and improves electrical properties.

Lithium bromide and chloride have proved more effective and cheaper than other deliquescent compounds when used in the absorbent brines for air-conditioning. Lithium chloride and fluoride in welding and brazing fluxes are characterized by low melting points, high boiling points, and high solvent power for metal oxides; they are especially useful in aluminum, magnesium, and titanium joining.

Other uses include lithium hydroxide as an additive in alkaline storage batteries to increase cell life and capacity; and in the manufacture of certain pharmaceuticals. A comparatively recent application of great importance is the use of lithium metal dispersions and butyl lithium as catalysts in the polymerization of isoprene to a "natural" synthetic rubber.

The most significant nuclear properties are the differing neutron-absorbing cross sections of the two natural isotopes, lithium 6 and lithium 7. Lithium 6 has a high cross section and can absorb neutrons; in certain nuclear reactions it can be converted to tritium and helium. Presumably lithium 6 is valuable in strategic applications, since the Atomic Energy Commission has treated chemicals purchased from the major producers for extraction of the $Li^6$ isotope.

Foote Mineral Company's general offices are at 18 West Chelten Avenue, Philadelphia. The research and development laboratories are at Berwyn, Pennsylvania; Kings Mountain, North Carolina; and Exton, Pennsylvania. In addition to the Kings Mountain installation, plants are at Exton, Pennsylvania; Cold River, New Hampshire; Knoxville, Tennessee; and Sunbright, Virginia.

**KEY PERSONNEL: An on-the-spot conference is held by H. M. Broadwater, plant engineer; E. R. Goter, general superintendent; and N. O. Johnson, operations manager, at the entrance to the Foote Mineral Company's Kings Mountain operations office.**

The company has more than 800 employes whose business is transforming the minerals in the earth's crust into useful industrial products. In August of 1959, ground was broken at the Indian Run property at Exton for construction of the main building of the new Research and Engineering Center. This building, costing more than $2,000,000, will ultimately accommodate about 175 scientists and engineers. This means that Foote is still in the business of probing for new products and developing them. In addition to this building, new plant and equipment expenditures for 1959 amounted to about $1,629,000, the largest single project being the expansion of one of the electrolytic manganese plants at Knoxville.

Foote has built up good employe relations. In 1959, the company paid its employes $564,761 under a profit-sharing bonus plan. These incentive bonus payments represented 10.4% of the gross payroll. About 50% of the bonus was paid in the company's common stock and the balance in cash.

Neil O. Johnson is manager of the company's Kings Mountain operation. Officers are Gordon H. Chambers, chairman of the board; L. G. Bliss, president; Felix B. Shay, vice president of production and engineering; John S. Gates, vice president of marketing; William R. Spofford, Jr., secretary and treasurer.

Directors, other than the officers, are Russell H. Bennett, mining engineer, Minneapolis; James Fentress, vice president, Baker Fentress and Co.; Robert J. Lewis, partner, Estabrook & Co.; J. Melville Stein, president, Leeds & Northrup Company.

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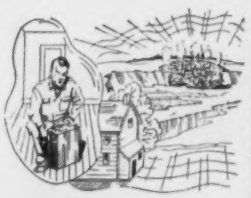

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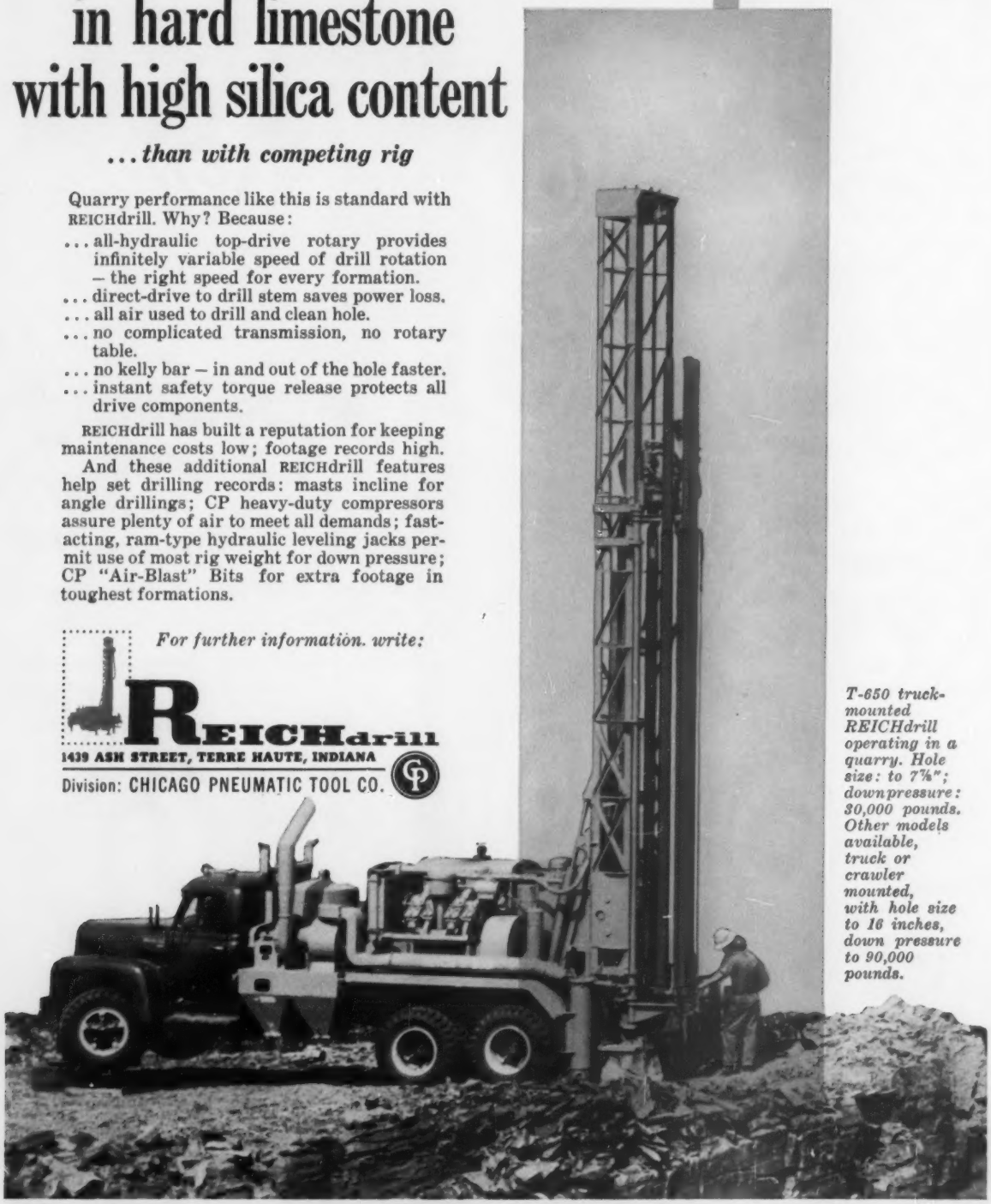

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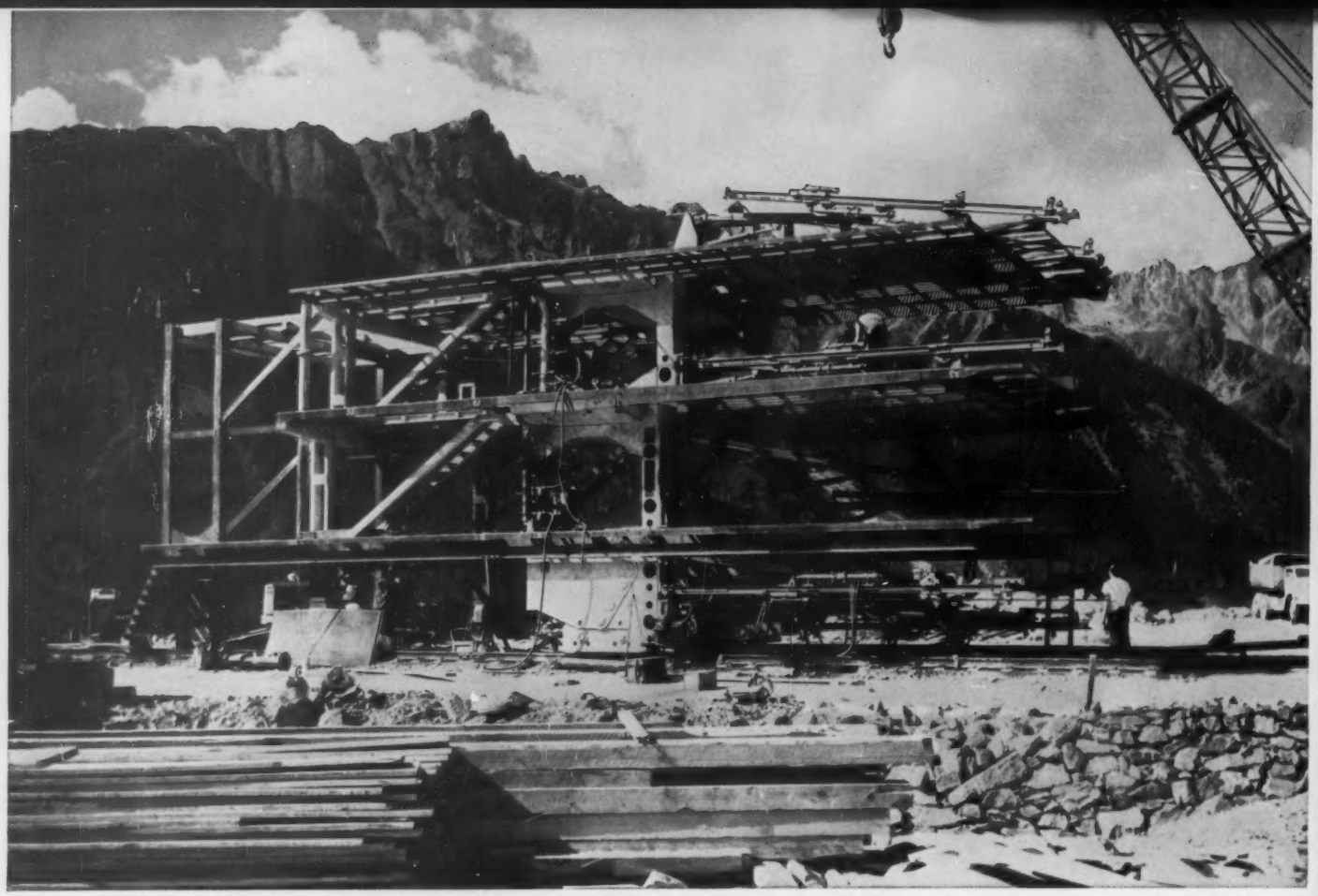

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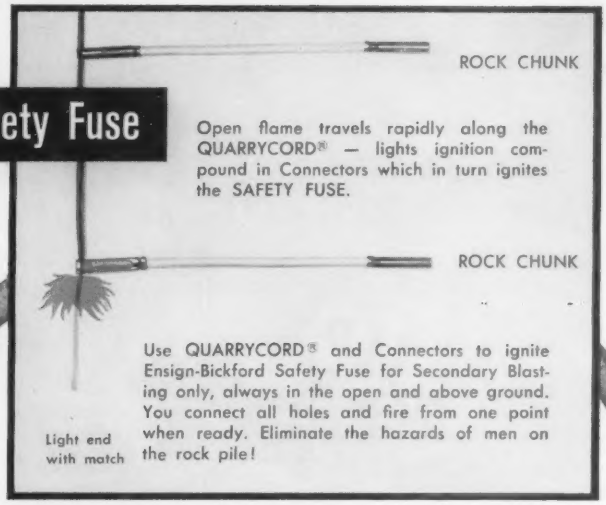


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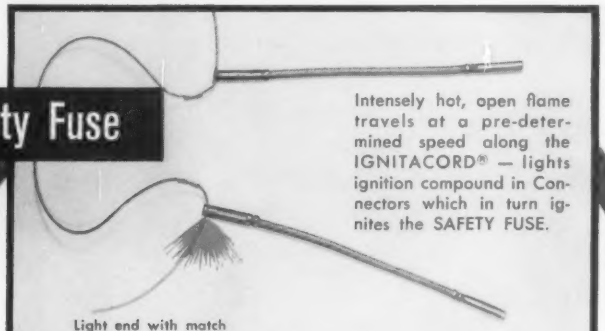
Use QUARRYCORD® and Connectors to ignite Ensign-Bickford Safety Fuse for Secondary Blasting only, always in the open and above ground. You connect all holes and fire from one point when ready. Eliminate the hazards of men on the rock pile!

## Ignitacord® and Safety Fuse




Intensely hot, open flame travels at a pre-determined speed along the IGNITACORD® — lights ignition compound in Connectors which in turn ignites the SAFETY FUSE.

Use IGNITACORD® and Connectors to ignite Ensign-Bickford Safety Fuse in underground Stoping, Heading and Development Rounds, When used as directed, Ignitacord provides positive rotation firing without fuse trimming, positive initiation with one-point lighting — greater safety with economy.

**Safety Fuse today – as it has over the years – offers economy, efficiency and safety. You can now use Safety Fuse in multiple-hole blasting and cut costs up to 30%**

Write for this free Safety Fuse Sample Kit and folders describing Quarrycord and Ignitacord.

S-1

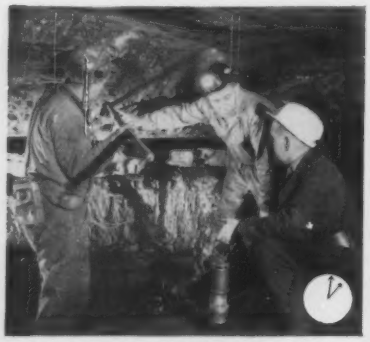
**THE ENSIGN-BICKFORD COMPANY, Simsbury, Conn. • Since 1836**

## *A Typical Day with a Hercules Representative*

**AN EARLY START** enables Bob Shiel, Hercules technical serviceman, to observe step-by-step blasting procedures at his customer's mine.

**CLOSE CONTACT** between Bob and the mine superintendent eliminates most blasting troubles, and increases the operating economy of the mine.

**UNDERGROUND** with the tools of the trade, Bob examines some of the cars of blasted material to determine the effectiveness of the explosive charges.



**BLASTING-PROCEDURE** observation is a part of Bob's work. It takes the guesswork out of his job, and enables him to specify the proper explosives.

**SHOP TALK** helps find out if the remedy he's suggested has cured this mine's troubles. Bob's background gives him the insight necessary to make intelligent recommendations.

**CHECKING** and rechecking all the recommendations he has made gives Bob the satisfaction of knowing that he has been of assistance in solving his customer's blasting troubles.

### Around the nation — around the clock

# THERE'S ALWAYS A HERCULES MAN READY TO HELP YOU

Bob Shiel, E.M., Ohio State, is just one of the many specially trained Hercules men serving the explosives-consuming industries. For years Hercules has employed men with engineering training to sell and service its explosives throughout the United States and in many foreign lands. Our experience has proved that men with engineering training can meet their customers on common ground. They speak the same language, for most of the men who direct explosives-consuming work are technically trained.

When a young engineer starts his training as an explosives sales engineer with Hercules, he begins a period of orientation. He is then sent to our explosives plants and laboratories for thorough groundwork in products and processes. Upon completion of this indoctrination, he visits various sections of the country where he learns how explosives are used in underground and open-pit mines, rock quarries, heavy-construction jobs, and seismic exploration.

The cornerstone of Hercules Explosives Department is based on men who have the know-how to handle blasting problems quickly, efficiently, economically. To take advantage of this specialized service, call or write.

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